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THE SOUTHERN BLUEFIN TUNA, *THUNNUS THYNNUS MACCOYII* (CASTELNAU), IN AUSTRALIAN WATERS

By D. L. SERVENTY*

[*Manuscript received April* 26, 1955]

Summary

This paper deals with the results of the investigations of the Division of Fisheries, C.S.I.R.O., into the biology of the southern bluefin tuna (*Thunnus thynnus maccoyii* (Castelnau)), a representative in southern Australia and New Zealand of the tunny of Europe and the bluefin tuna of California.

A comparative description of the morphology of the Australian form is given with a detailed study of its occurrence in Australia, including a discussion of the possible presence of local breeding stocks. The growth rate is considered from a study of length frequency data. Considerable variations have been found in the growth rate of the younger age classes, as well as fluctuations in their relative abundance and their migratory movements along the eastern Australian coastline. Reference is made to the feeding habits in various areas.

I. HISTORICAL

The Australian form of the tunny of Europe or bluefin tuna of North America, *Thunnus thynnus* (L.), locally known as the southern bluefin, is the most widely spread and predominant tuna in southern Australia but, though its presence was recorded from the earliest times of exploration, it had remained virtually unknown and its real abundance quite unappreciated until the Division of Fisheries, C.S.I.R.O., began its investigations in 1936. S. Fowler of this Division, in his surveys by vessels and aircraft in south-eastern Australia, found it to be one of the two most plentiful tunas in the area. As an indication of the meagre state of knowledge which existed just prior to these investigations it is of interest to quote a comment by the Director of the South Australian Museum on a catch of the species near Adelaide. He referred to the species as a rare visitor and said that "it was 40 years since similar fish had been reported in South Australian waters" (*South Australian Advertiser*, Feb. 8, 1934).

The activities of the Division of Fisheries on pelagic fisheries problems, with a view to the stimulation of economic development, were from the outset largely directed at the tuna species. In the absence of any commercial fishery all the data had to be obtained directly by the Division. Before the commissioning of the research vessel F.R.V. *Warreen* in 1938, a number of small fishing craft were chartered, with S. Fowler as observer, and he also at intervals until 1946 carried out extensive aerial observations of pelagic fish shoals around most of the Australian coastline. The *Warreen* made surveys in eastern Australia between 1938 and 1942, making two visits to South Australia in 1939. World War II interrupted this programme and the vessel was taken over by the Royal Australian Navy. In 1947, when she was recommissioned for the Division, surveys were begun in Western Australia, and these ended in 1951 when economy measures necessitated the transfer of the vessel to the Navy. During 1949 and 1950 a second research vessel, the F.R.V. *Stanley Fowler*, operated in eastern and northern Australia. No significant commercial fishery for any tuna species developed until 1949, when the southern bluefin became the subject of a troll fishery; this is still not securely established. It will be appreciated, therefore, that facilities for collecting and observing have always been very limited, and much more so at some times and places than at others.

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The southern bluefin in Australia (Plate 1, Fig. 1) is an inhabitant of southern waters only, but in the older records its northern distribution in eastern Australia had been greatly exaggerated owing to confusion with the northern bluefin, *Kishinoella tonggol* (Bleeker). It appears to occur as two geographic groups (see Fig. 1). In south-eastern Australia it ranges from as far north as Sydney (lat. 34° S.) around the New South Wales and Victorian coastline to Port Phillip, and is found in eastern Bass Strait and northern, eastern, and southern Tasmania. After a short gap in south-western Victoria, western Bass Strait, and western Tasmania, where the species appears to be only a straggler, it reappears in strength in South Australia and is then continuously distributed around south-western Australia as far north as Cape Inscription (lat. 25° 30′ S.). The South Australian population sometimes extends as far east as Port Fairy in Victoria and the west coast of King Island.

There are no records from Lord Howe Island or Norfolk Island. In New Zealand specimens have been taken from Foveaux Strait in the south to the Bay of Islands in the north.

Perhaps the first reference to the occurrence of this tuna in Australian waters was that of François Péron in his account of the French navigating expedition in the *Geographe* and the *Naturaliste* (1807, vol. 1, p. 322). When the expedition was near Rivoli Bay, S.A., on April 5, 1802, it sighted "une troupe nombreuse de Scombres de la grandeur de nos Thons (*Scomber thynnus*, Lacépède), mais dont il me faut impossible de distinguer exactment l'espèce". As the southern bluefin is the only tuna species known to occur in that part of South Australia there can be no doubt that it was this species Péron witnessed. It is still particularly plentiful in the area.

The next published reference was by McCoy (1867, p. 317), who mentioned that the tunny was a not uncommon visitor and designated it a new species, *Thynnus australis*, a name which lapses not only because it is a *nomen nudum* but because it is preoccupied (by Boisduval in 1835 for a hymenopteran). In 1869, portions of a large specimen, which had been stranded at Spring Bay, Tas., were exhibited at a meeting of the Royal Society of Tasmania (Anon. 1870).

The specific name *maccoyii* was bestowed by Castelnau (1872, vol. 1, p. 104), the comment being made that "the flesh of this fish is not eaten, or at least is not esteemed as food. It is very scarce at Melbourne; those I saw appeared towards the end of November." In the same year Hutton (1872, p. 22) doubtfully attributed a large skull from Cook Strait to *Pelamys chilensis* (= *Sarda chilensis australis* Macleay), but which (as I verified from personal examination of the specimen in 1949) is the present species. In 1880 McCoy gave a detailed description, with a coloured plate, of Victorian specimens.

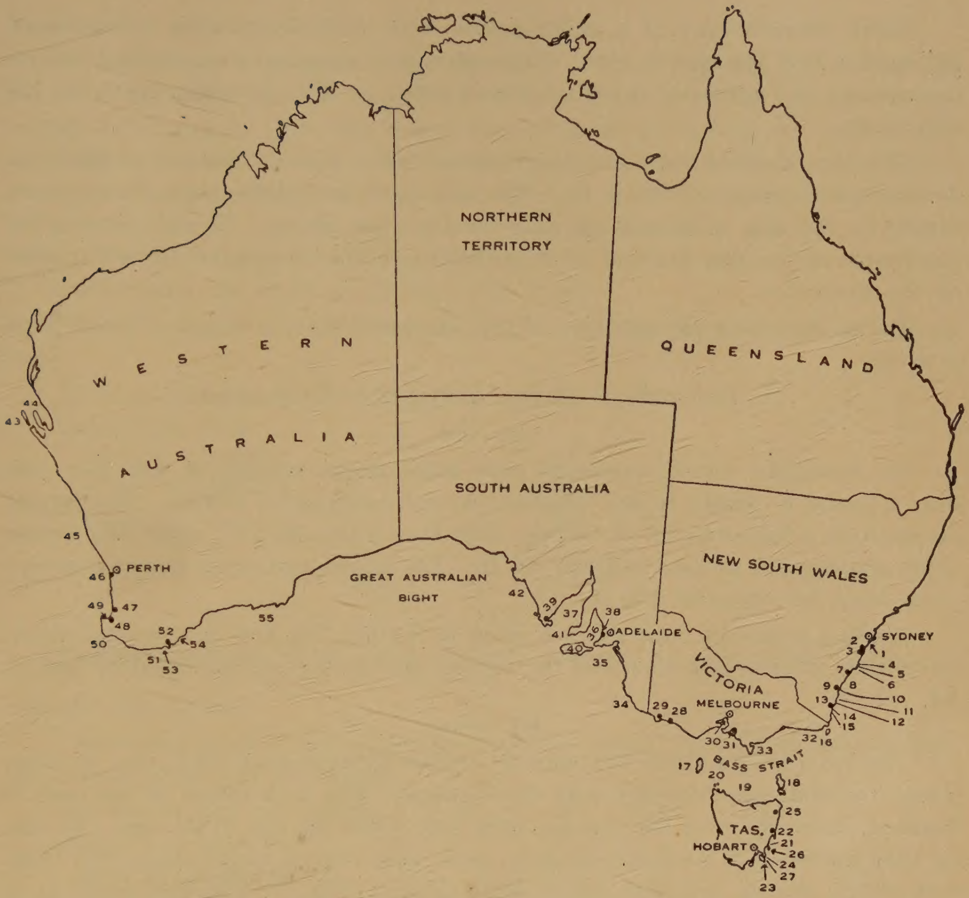
NORTHERN TERRITORY
QUEENSLAND
WESTERN AUSTRALIA
SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
TAS.
GREAT AUSTRALIAN BIGHT
BASS STRAIT
PERTH
ADELAIDE
MELBOURNE
SYDNEY
HOBART

Fig. 1.—Map of Australia, showing localities referred to in the text.

New South Wales

1. Port Hacking
2. Port Kembla
3. Wollongong
4. Shoalhaven Bight
5. Point Perpendicular
6. Jervis Bay
7. Ulladulla
8. Brush I.
9. Narooma
10. Montague I.
11. Bermagui
12. Merimbula
13. Eden
14. Twofold Bay
15. Green Cape
16. Gabo I.

Tasmania

17. King I.
18. Flinders I.
19. Furneaux Group
20. Three Hummock I.
21. Spring Bay
22. Bicheno
23. Cape Pillar
24. Fortescue Bay
25. St. Helens
26. Cape Peron
27. Hippolyte Rocks.

Victoria

28. Port Fairy
29. Portland
30. Port Phillip Bay
31. Westernport Bay
32. C. Everard
33. Wilson's Promontory

South Australia

34. Rivoli Bay
35. Backstairs Passage
36. St. Vincent's Gulf
37. Spencer's Gulf
38. Glenelg
39. Port Lincoln
40. Kangaroo I.
41. Investigator Strait
42. Anxious Bay

Western Australia

43. Dirk Hartog I. (Pt. Inscription)
44. Shark Bay
45. Jurien Bay
46. Fremantle
47. Bunbury
48. Busselton
49. Geographe Bay
50. C. Leeuwin
51. Nornalup Inlet
52. Albany
53. Frenchman Bay
54. Cheyne Beach
55. Archipelago of the Recherche

Later references are of a minor nature until 1907 when, after a large shoal appeared in Port Hacking in June of that year and a specimen was captured, several descriptions and accounts appeared (Stead 1907, p. 392; Roughley 1916, p. 164 and plate).

The New Zealand form was described as a new species, *Thunnus phillipsi*, by Jordan and Evermann (1926, p. 13). This was based on a photograph of a specimen caught in the Bay of Islands showing an abnormal snout. Though no detailed description of the New Zealand form has been published it appears to be the same as the Australian.

Before discussing the affinities of the Australian form a summary description is given.

II. DESCRIPTION OF THE AUSTRALIAN POPULATIONS

(*a*) *Size*

In Australian waters specimens have been caught ranging in size from just over a pound in weight to fish weighing several hundreds of pounds. The largest on record is a fish stranded at Glenelg, near Port Adelaide, S.A., some time before 1890, and reputed to have weighed 800 lb. The largest specimens caught in recent years have not exceeded 300 lb.

Further details of large fish are given in Section VII and the regional distribution and relative abundance of the various size groups are discussed in Section VI.

(*b*) *Colour*

The back is blue-black but may in various lights appear royal blue or blue-green; the abdomen is silvery with no markings. The dark colour of the back is confined, ventrally, to a line running from just above the eye to the keel. In life, or when the fish is in its death throes on deck, pale vertical bands appear but these may vanish quickly and often before death (Plate 1, Fig. 2). The first dorsal fin is grey with a yellow tinge; the dorsal finlets yellow, bordered with black submarginally and edged with white. The anal fin is silvery grey; the anal finlets yellow bordered with black and narrow white external edge posteriorly. The caudal fin is dark grey with yellow submarginal stripe. The pectoral fin is dorsally like the back; underneath silvery grey. The caudal keel is yellow.

Small specimens lack yellow entirely or reveal only olivaceous tones where this will later develop.

(*c*) *Fin Formulae*

The following are the frequencies of spines and rays in the various fins:

First dorsal fin

Number of spines	12	13	14
Individuals from:			
Eastern Australia	3	383	453
South Australia	—	23	46
Western Australia	1	34	30
Total:	4	440	529

Second dorsal fin and finlets

As has already been pointed out (Serventy 1942, p. 103) this fin and the anal are thick and fleshy and the skin must be scraped off to expose the rays clearly enough for counting. Thus only counts which have been made in this manner have been used here. As the most anterior finlet, in both the dorsal and ventral series, is not infrequently adnate to the second dorsal and anal fins respectively, and as the posterior dorsal and anal rays resemble the finlets in form and size it is sometimes difficult to distinguish between them and for taxonomic purposes it is better to consider only the totals of fin rays and finlets.

The following total counts were recorded in samples from the various regional areas:

Number of rays and finlets	22	23	24
Individuals from:			
Eastern Australia	1	97	2
South Australia	—	26	—
Western Australia	—	29	—
Total:	1	152	2

Usually there are 15 second dorsal rays followed by eight dorsal finlets.

Anal fin and finlets

The total number of combined anal rays and ventral finlets from samples from the various areas was as follows:

Number of rays and finlets	21	22	23
Individuals from:			
Eastern Australia	2	94	2
South Australia	—	30	—
Western Australia	—	16	1
Total:	2	140	3

Usually there are 14 anal rays followed by eight ventral finlets.

Pectoral fin

Number of rays	28	29	30	31	32	33	34	35
Individuals from:								
Eastern Australia	—	—	1	18	43	15	4	—
South Australia	—	—	—	2	6	6	1	—
Western Australia	1	—	—	14	20	17	7	—
Total:	1	—	1	34	69	38	12	—

The fin formula for the species is D. 12-14, 14-15, 8-9; A. 14-15, 7-8; P. 28-34. The most usual is: D. 14, 15, 8; A. 14, 8; P. 32.

(*d*) *Scale Rows*

The count, for 12 specimens, ranged from 207 to 235 scales from the operculum to the caudal peduncle, with a mean of 218.

(*e*) *Gill-rakers*

The gill-raker frequencies are as follows:

Dorsal limb

Number of rakers	9	10	11	12	13
Individuals from:					
Eastern Australia	2	16	38	19	4
South Australia	—	1	11	2	2
Western Australia	8	48	105	52	3
Total:	10	65	154	73	9

Ventral limb

Number of rakers	21	22	23	24	25	26	27	28
Individuals from:								
Eastern Australia	4	35	32	7	1	—	—	—
South Australia	2	4	6	2	2	—	—	—
Western Australia	18	74	87	32	4	—	—	1
Total:	24	113	125	41	7	—	—	1

Total

Number of rakers	31	32	33	34	35	36	37	38	39	40
Individuals from:										
Eastern Australia	3	12	26	15	17	3	3	—	—	—
South Australia	—	3	3	5	1	2	2	—	—	—
Western Australia	6	41	52	63	34	18	1	—	—	1
Total:	9	56	81	83	52	23	6	—	—	1

The gill-raker formula is, therefore, 9-13/21-28 = 31-40. The modal formula is 11/22-23 = 33-34.

There is virtual identity in the relative proportions in samples from the extreme east and west of the range.

(*f*) *Morphometric Characters*

The standard measurements as recommended by the International Commission for the Exploration of the Mediterranean (1932; see also Russell 1934*b*), as modified by Serventy (1942, p. 104), have been made (in centimetres) on a number of specimens throughout the Australian range of the species. The original data are held by the Division of Fisheries, C.S.I.R.O., Cronulla.

Linear regression equations were fitted to the logarithms of the dependent and independent variables in each case, giving equations of the form

$$\log\ Y = \log\ a + b\ \log\ x,$$

which in terms of the original units is a parabola with (usually) a non-integral index, thus:

$$Y = ax^b\ .$$

This relationship was chosen since in common with other biological data the larger measurements exhibit much greater variability than the smaller, resulting in heterogeneous errors of estimate in the different size groups. The variance becomes relatively more stable for all sizes when the logarithms are used.

The method of comparison of the samples (i.e. from eastern, southern, and Western Australia) amounts to the comparison of the linear regression coefficients in the various log-log relationships. If the relationships are linear then the interpretation of significant differences of the coefficient is relatively simple. If they are curvilinear, differences in the coefficients may merely reflect differences in range of fish sizes in the various samples. That is, caution must be exercised in interpreting significant differences in the coefficients if the ranges of size differ. The eastern and southern samples cover similar ranges but the western sample consists of much smaller fish. Although these samples show no evidence of non-linearity (i.e. rectification was achieved with log-log transformation for all characters), comparisons involving the sample from Western Australia are made with the reservation that data from larger fish might possibly yield different results.

Some investigators (e.g. Schaefer 1955) have had to use transformations other than log-log in order to achieve rectilinearity in working with certain morphometric characters in tuna.

The results of the computations and a summary of the comparisons between the samples are set out in Table 1, where $\bar{x}$ = the mean of values of x; $\bar{y}$ = the mean of values of y; $s_{y.x}$ = the standard deviation from regression (standard error of estimate); b = regression coefficient of y on x; and n = number of specimens. The columns headed "Homogeneity of Regression Coefficients" give the significance (if any) of the various comparisons; the first column giving the significance pertaining to the comparison of the coefficients taken three at a time, and the next three columns the comparisons of the pairs.

It is clear that in several parts of the body, differential (heterauxetic, allometric, heterogonic, or relative) growth occurs, the part growing at a faster or slower rate than that of the body as a whole. The existence of this may be readily ascertained from the magnitude in Table 1 of b, which is the regression coefficient of y (the part or organ concerned) on x (the body length or other standard to which the organ is compared); J. S. Huxley has called it the growth coefficient of the organ. When b is unity, or nearly unity, the organ increases proportionately with the body length. When b is less than unity the organ may be said to be growing at a slower rate (in actual fact, a continuously decreasing rate) than the body. Similarly when b is greater than unity the organ is growing at a greater rate (namely, a continuously increasing rate) than the body.

TABLE 1

STATISTICS DESCRIBING REGRESSIONS OF BODY PROPORTIONS OF THUNNUS THYNNUS MACCOYII FROM VARIOUS AREAS

L.C.F., length from snout tip to caudal fin fork

Independent Variable	Dependent Variable	Southern Australia					Eastern Australia					Western Australia					Homogeneity of Regression Coefficients (b's)			
x	y	$\bar{x}$	$\bar{y}$	$s_{y.x}$	b	n	$\bar{x}$	$\bar{y}$	$s_{y.x}$	b	n	$\bar{x}$	$\bar{y}$	$s_{y.x}$	b	n	Over-all	S.A. v. E.A.	E.A. v. W.A.	W.A. v. S.A.
Log L.C.F.	Log snout to origin of 2nd dorsal fin	1.8586	1.6104	0.0049	0.9630	78	1.8261	1.5777	0.0048	0.9596	206	1.7475	1.5026	0.0058	0.9701	14	N.S.			
Log L.C.F.	Log head length	1.8586	1.3447	0.0067	0.9994	78	1.8350	1.3203	0.0071	1.0660	290	1.7308	1.2116	0.0070	0.9992	15	***	***	***	N.S.
Log L.C.F.	Log greatest depth	1.8703	1.2922	0.0113	1.0134	47	1.8353	1.2596	0.0123	0.9609	185	1.6226	1.0432	0.0102	1.1190	13	**	*	**	N.S.
Log L.C.F.	Log height of 1st dorsal fin	1.8558	0.9073	0.0212	1.0077	74	1.8303	0.8738	0.0220	1.0607	236	1.7192	0.7815	0.0178	1.0003	17	N.S.			
Log L.C.F.	Log length of anal fin	1.8586	0.8665	0.0199	1.4996	78	1.8301	0.8320	0.0204	1.5202	235	1.7331	0.7046	0.0277	1.2968	16	***	N.S.	***	***
Log L.C.F.	Log snout to vent	1.8586	1.6445	0.0047	0.9604	78	1.8269	1.6158	0.0061	0.9698	207	1.6182	1.4187	0.0072	1.0687	12	***	N.S.	***	***
Log L.C.F.	Log snout to origin of ventral fin	1.8586	1.3920	0.0090	0.9673	78	1.8260	1.3607	0.0087	1.0178	205	1.7475	1.2773	0.0130	1.0044	14	**	**	N.S.	*
Log L.C.F.	Log height of 2nd dorsal fin	1.8586	0.8825	0.0174	1.3676	78	1.8304	0.8474	0.0201	1.5129	237	1.7331	0.7143	0.0161	1.2399	16	***	***	***	***
Log L.C.F.	Log depth of body at 1st dorsal fin	1.8586	1.2654	0.0086	1.0258	78	1.8313	1.2376	0.0109	1.0369	240	1.6963	1.1052	0.0130	1.0203	14	N.S.			
Log L.C.F.	Log snout to origin of 1st dorsal fin	1.8586	1.3639	0.0073	0.9674	78	1.8261	1.3322	0.0086	0.9920	203	1.7475	1.2631	0.0078	0.9544	14	*	N.S.	**	N.S.
Log L.C.F.	Log pectoral fin (erect)	1.8586	1.1307	0.0188	1.1495	78	1.8373	1.1130	0.0208	1.2613	311	1.7308	0.9861	0.0290	1.0043	15	***	**	***	***
Log L.C.F.	Log length of pectoral fin (extended)											1.6203	0.9033	0.0159	1.3078	14				
Log head	Log orbit	1.3447	0.4786	0.0269	0.7213	78	1.3157	0.4609	0.0182	0.6362	247	1.2116	0.3950	0.0248	0.6927	15	*	*	*	N.S.
Log head	Log maxillary length	1.3436	0.9384	0.0069	0.9467	75	1.3076	0.9030	0.0069	0.9822	201	1.2290	0.8345	0.0082	0.9359	14	***	**	***	N.S.
Log head	Log pre-opercular	1.3447	1.2558	0.0157	0.8944	78	1.3145	1.2239	0.0050	0.9948	238	1.2140	1.1299	0.0063	0.9927	16	***	***	N.S.	***
Log body depth at 1st dorsal fin	Log inter-axillary diameter	1.2654	1.1275	0.0091	1.1055	78	1.2337	1.0894	0.0131	1.1443	212	1.1310	0.9612	0.0193	1.0537	12	***	N.S.	***	*

*$P<0{\cdot}05$. ** $P<0{\cdot}01$. *** $P<0{\cdot}001$. N.S., not significant.

The parts showing extreme differential growth are the diameter of the orbit, the lengths of the pectoral and anal fins, and the height of the second dorsal fin.

Table 1 shows that significant differences have been found in certain characters between southern and eastern, eastern and western, and western and southern fish. These groups might therefore represent different populations; the matter is further discussed in Section IX.

(*g*) *Other Relationships*

The pectoral fin most commonly reaches to the vertical passing between the 12th and 13th dorsal spines, but may fall short as far as the level of the 10th-11th spines or be as far beyond as the 13th-14th spines.

(*h*) *External Abnormalities*

Occasionally specimens are met with showing various abnormalities in external structures, mostly, no doubt, due to accidents. In one fish the anal fin was entirely missing, save for the last ray, the scar being clean and long healed. Another had the hinder part of the first dorsal fin missing and replaced by a clean scar. Another lacked the anterior part of the pelvic fin, the space being occupied by a clean scar; the vent was displaced a little to the right of the mid-ventral line. Missing finlets, both in the dorsal and ventral series, were more frequent. The caudal keels also might be affected. In one fish the right lateral keel was entirely missing, a clean scar being present. In another only a small portion remained of the posterior part of the left lateral keel.

The presence of these abnormalities in nature reduces the possible value of finlet clipping for marking experiments.

The facial abnormality in the type specimen of the New Zealand *phillipsi* (Jordan and Evermann 1926, Plate 2, Fig. 4) has not so far been encountered among Australian individuals examined by the author but it has been seen in occasional Australian specimens of *Thunnus germo* Lacépède.

(*i*) *Liver*

The liver (Serventy 1941*a*, Fig. 9; Plate 2 of this paper) resembles the accounts of that organ in other members of the species group, but Frade's (1925, p. 8) description that in the European tunny the median lobe is more pointed and the right lobe is more developed than in *T. orientalis* does not apply to our form. In these respects the liver of the Australian fish accords more with those of Japanese and Californian populations, despite the statement of Godsil and Holmberg (1950, p. 14) that in the Australian fish the liver shape is more irregular and the lateral lobes are longer. This may be due to individual differences, but their statement does not appear to apply to the average condition, and our fish certainly do not have as long lateral lobes as those figured by Frade for Atlantic fish. Perhaps a more consistent characteristic of Australian fish, as compared with extra-limital forms, is the more *pointed* lateral lobes (Plate 2).

The liver shows differential growth during the early years of the life of the fish. It has been found from many weighings of various-sized fish that the mean value of the ratio liver weight : body weight is between 1·7 and 1·9 per cent. in the second-year fish (5-8 lb body weight) and rises to a maximum of 2·2 per cent. of the body weight in three-year-old fish (17 lb body weight). Thereafter the percentage falls until it is about 1·8 per cent. in four-year-old fish (28 lb body weight) and 1·2 per cent. in 40-lb fish. In larger fish it is about 0·9 per cent. with little variation from that value.

Raven and La Monte (1937) state that in swordfish the liver is heavier proportionately in the smaller fish while Conrad (1940) has found "a constant differential growth rate of the liver".

(*j*) *Swim Bladder*

The swim or air bladder is only fully developed in large, mature fish, but is present as a rudiment in even the smallest individuals in the median anterior portion of the body cavity, as indicated by Godsil and Byers (1944, p. 93, Fig. 51). It increases in size in relation to the body cavity during growth but is very irregular in shape in the intermediate stages. In fish about 30 lb in weight (length, snout to caudal fork, 87 cm), it has reached about half the length of the body cavity, being about 6½ by 2½ in. in dimensions and of a triangular shape, wide at the anterior end. In fish of about 62 lb weight (114 cm in length) the swim bladder has spread to the entire width of the body cavity anteriorly and is about two-thirds its length (Fig. 2, *A*-*B*). In fish over 100 lb in weight (length 138 cm), the swim bladder occupies the entire dorsal roof of the body cavity, except along its lateral posterior margins where a narrow space exists on each side. This fully developed swim bladder is quite different in appearance from that in the intermediate growth stages (Fig. 2*C*). It is strongly pyriform in shape and the posterior end, which extends right to the vent,

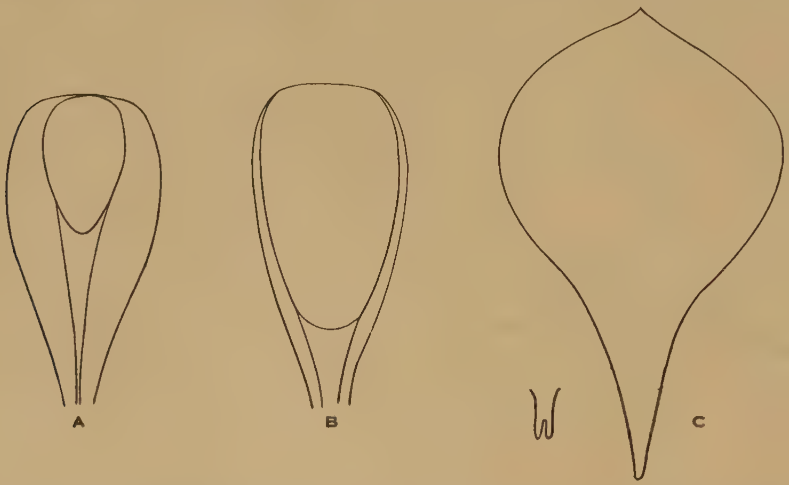

Fig. 2.—Swim bladders in immature southern bluefin. *A*, in a fish of weight 31 lb and length (to caudal fork) 87 cm. *B*, in a fish of weight 62 lb and length 114 cm. *C*, swim bladder of adult southern bluefin, of weight 264 lb and length 164 cm; inset, bilobed posterior end.

is bifid or bilobed. The swim bladder at this stage is very similar to that described and illustrated by Frade (1925, p. 9, Fig. 1) for the European tunny except that in the Australian form there is only a single, not a double, dilatation at the anterior end. Neither Kishinouye (1923, p. 438) nor Godsil and Byers (1944) have examined fully grown specimens for a description of the swim bladders as they exist in tunas in their areas. Thus Kishinouye states that in *T. orientalis* the air bladder occupies a little more than half the length of the body cavity and its shape is triangular and pointed at the posterior end. This description and his illustration (Fig. *L*, 2, p. 355) would fit exactly an Australian fish of about 60 lb weight. The largest fish measured by Godsil and Byers was 89 cm, and consequently they were able to find only a rudimentary structure of variable size and shape, but never bigger than slightly over 3 in. in length.

(*k*) *Other Characters*

A painstaking investigation of the anatomy of the southern bluefin has been published by Godsil and Holmberg (1950), who found the following features to be significantly different from those in other populations of the species group: the vent is smaller than in Californian and western Atlantic fish; there is a shorter abdominal cavity; there are smaller tubules in the pyloric caecal mass, form differences in the liver and kidneys, differences in curvature of the dorsal body wall, and differences in the swim bladder, details of the branching of the coeliaco-mesenteric artery, the form of the pelvic girdle, and the shape of the first haemal arch. The significances of some of these differences are discussed in Section III.

III. Affinities

The southern bluefin is obviously a member of the species group which contains the European great tunny (*Thunnus thynnus* (L.)) from the eastern side of the north Atlantic, *T. secundodorsalis* (Storer) (which should properly be known by the earlier name *T. coretta* (C. & V.)) from the western Atlantic, *T. saliens* Jordan & Evermann from the Pacific coast of North America, and *T. orientalis* (Temminck & Schlegel) from the seas around Japan. Opinion has long been divided whether all of these local forms should be considered as members of one wide-flung but discontinuously distributed species, or whether they are better considered as fully differentiated species. In recent reviews Fraser-Brunner (1950)* has subscribed to the former view and Godsil and Holmberg (1950) to the latter. In my opinion the evidence favours the acceptance of one species only.

The species group occurs in temperate and warm-temperate waters as six isolated populations. In the northern hemisphere there are populations in the east and west Atlantic with no real evidence that migration occurs across the ocean. In the North Pacific there is a similar distribution of the species. In the southern hemisphere, widely separated from the northern populations by the tropics, two populations are known: one in the southern Australian and New Zealand region and the other in South Africa. It is curious that no member of this species group has been met with in South America. The South African fish, though geographically sharply marked off from the north Atlantic stocks, have always been referred to the species *T. thynnus* and have never been given a separate name as a local species.

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* Fraser-Brunner's placing of the name *maccoyii* in the synonymy of *Thunnus* (*Parathunnus*) *obesus* Lowe, 1839, was an inadvertence and he agrees that it is a member of the *thynnus* group (*in litt.*, August 1950).

Comparison of the description just given of the Australian population, and that of Godsil and Holmberg (1950), with accounts published of extra-limital forms show that the relations between them all are quite close. In respect to fin formula there is virtual identity between my values for the Australian fish and the detailed account presented by Godsil and Byers (1944) for the Californian and those of Frade (1931) in his detailed analysis of the European form. My data also tally with other descriptions from various localities (e.g. Ehrenbaum 1936, p. 252; Tortonese 1939, p. 324, Japan; Kishinouye 1923, p. 437, Japan); and where they differ (as in Barnard 1927, p. 798, South Africa), it is probably due to the fact that these other authors have failed to count with sufficient accuracy the obscured rays in the second dorsal and anal fins.

My gill-raker counts show a slight difference from those in all other areas, where sufficient data are available for comparison. The modal figures are as follows:

Australia: 11/22-23 = 33-34,
California: 12/23-24 = 35-36,
Japan: 12-13/24-26 = 36-39,
Europe: 13/24-26 = 37-39.

Though there is a considerable overlap it is clear that we have here regional differences. There are fewest gill-rakers in the Australian population, the numbers increasing in the Californian and Japanese and being greatest in the European. High gill-raker numbers are reported from both the American and European sides of the North Atlantic.

In their detailed study of the Californian population Godsil and Byers (1944, p. 102) were able to find only two characters in which it appeared to differ significantly from the Japanese form: the shape of the swim bladder and the mode of origin of the cutaneous arterioles from the cutaneous artery. Godsil and Byers in their comparison of Australian, Californian, and Atlantic samples (1944, p. 35) set out a number of characters which differ in the various forms and on which they advocate their specific separation, as already mentioned.

Some of these differences arise from comparisons having been made between different-sized fish. Thus, I have suggested in the foregoing account of the Australian fish that Kishinouye had apparently described his swim bladder from an immature individual and that it could be matched with Australian fish of the intermediate size group. Australian adults do not differ essentially from European adults of similar size. It would appear likely that when adults only are compared the American and Japanese fish will also be found to conform to type.

The supplementary findings of Godsil and Holmberg (1950, p. 45) suggest that some of these supposed differences, such as curvature of the dorsal body wall, also vary with size. Examination of additional specimens suggests that their further diagnostic characters, concerning the arterial system, shape of the haemal arch, and others, may also be in this category and that though there may be differences in the various regional groups the differences for the recognition of particular individuals are not decisive.

There are differences in colour between the various populations which deserve attention though they have not been fully studied by authors. Godsil and Holmberg draw attention to this character but were prevented from using it fully owing to their material having been in a frozen condition for some time. The Australian fish have none of the rows of pale spots on the abdomen and flanks of the Californian fish (*fide* Walford 1937, Plate 34) which also appear to occur on the Atlantic fish (Godsil and Holmberg 1950, p. 7) and on the Japanese (Kishinouye 1925, p. 438), where "the belly is greyish with many pale transverse lines and rows of pale dots in alternation". There are also marked regional differences in fin colour. The Californian fish lack any marked yellow colour on the fins and finlets—hence the local vernacular name of "bluefin". The Japanese fish differ from them in that the second dorsal fin has a yellow tip and the dorsal finlets are yellow. This yellow coloration is even more extensively developed in the Australian fish; there is a yellow tinge on the second dorsal fin, both the dorsal and ventral series of finlets are yellow, and the caudal fin has a bright yellow stripe. This difference in fin coloration between Australian and Californian fish has been noted by fishermen with first-hand experience of both and has caused a great deal of confusion in identification (many local reports of yellowfin tuna have proved to be mis-identifications of the southern bluefin).

Introducing a "new, biochemical basis for taxonomy", Bills *et al.* (1937, p. 445) showed that the bluefin tunas of New England, California, and Japan had different amounts and potencies of vitamins A and D and considered their results warranted the separation of these populations as different species. However, the possible environmental causes of these differences were not taken into account.

Considering all characters it appears that the differences which are perceptible between the various stocks are of an order which distinguishes subspecies or geographical races and are not adequate species differences on modern concepts. The several species and populations already described can be considered as geographically replacing forms of one species, *Thunnus thynnus* (L.). These could be designated by the currently used trinomial nomenclature as follows:

Thunnus thynnus thynnus (L.), 1758—European seas.
T. t. coretta (C. & V.), 1831—North America, Atlantic coast.
T. t. subsp.—South Africa.
T. t. saliens Jordan & Evermann, 1926—North America, Pacific coast.
T. t. orientalis (Temminck & Schlegel), 1842—Asiatic coast of the North Pacific.
T. t. maccoyii (Castelnau), 1872—Australia and New Zealand.

The South African population has remained unnamed, but, from a consideration of the morphological differentiation which has gone on in similar isolated populations (*fide* in particular the work of Godsil and Holmberg) it will probably require designation as a new subspecies when its characters have been worked out.

IV. Growth Rates

The great majority of the fish caught in Australia by present methods of fishing are immature specimens weighing up to about 40 or 50 lb. The largest caught by the F.R.V. *Warreen* in her trolling experiments between 1938 and 1951 weighed 91 lb (South Australia). Most of these fish fall into three well-defined size groups in south-eastern Australia and two size groups in Western Australia. These, taken together, comprise four size groups which probably represent successive age classes.

Length frequency measurements at intervals throughout the year show that growth takes place almost entirely in the summer months, between October and May (Fig. 3, data from Tables 2-7). From May to October barely any increment in length or weight is gained by the fish.

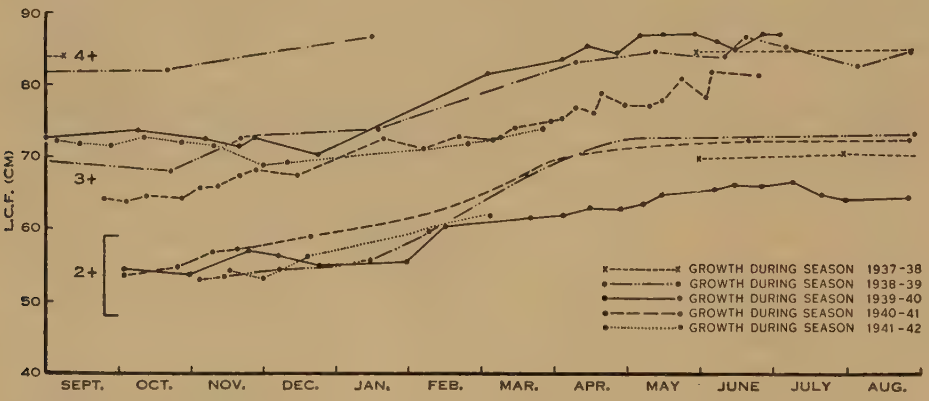

Fig. 3.—Progression of the means or modes, or both, of the length frequencies of the 2+, 3+, and 4+ age groups.

Fish presumed to belong to the 0+ age group have only been taken so far in Western Australia. The smallest known specimen is a fish trolled by the *Warreen* south of Albany, at the 100 fm line on March 25, 1951, which weighed 1 lb 5 oz and measured 31·8 cm (= 12½ in.) in length (snout to caudal fork).

By the end of the first growing period this size group has attained a mean length of 41 cm and a mean weight of 3·4 lb (based on combined length frequencies for May, June, July, and August for several years' Western Australian accumulated data). The observed range is from 34 to 50 cm, and from 1 to 6 lb.

By the end of the second growing season in Western Australia the 1+ age group has attained a mean length of 61 cm and a mean weight of 10½ lb, the observed ranges being 52-66 cm and 8-13 lb (data as before from the combined length and weight frequencies for the period May to August for several years).

For the notation of the age groups we may conveniently select the start of the summer growing period as a conventional "birthday" point. Thus at September the 0+ age group may be said to pass into the 1+ year class, and so on. The actual ages may be slightly different by a few months, as the season of hatching is not known.

In Western Australia comparatively few immature fish older than the 1+ age group have been caught by trolling in the inshore waters. However, between March and June 1951, when bluefin were unusually plentiful on the south coast in the Albany area, the *Warreen* trolled a significant proportion of larger fish belonging to the 2+ age group. In South Australia and south-eastern Australia, however, while the 0+ age group has not so far been taken, the commercial catch by trolling is made up of 1+, 2+, and 3+ age groups. That the eastern fish of the 1+ age group are not of identical origin with the same age group in Western Australia is suggested by the difference in average size. They are almost always smaller than the western fish. In other words the growth rate is faster in the west than in the east, at least for this portion of the life cycle; the difference does not appear to be so marked between western and eastern fish of the 2+ age group, but adequate samples of the western fish for comparison are at present lacking.

The 1+ age group first appears in the New South Wales fishery about the beginning of October, i.e. when on our conventional reckoning of age it is passing into the 2+ age group or entering its third year of life. In contrast to the western fish it has a mean length of only 53 cm at this stage (compared with 61 cm) with a mean weight of 6½ lb, but there is considerable variation from year to year. The South Australian members of this age group are sometimes slightly larger than south-eastern Australian fish (as in the summer of 1938-39) and sometimes equivalent (as in the summer of 1939-40) but sufficient comparable samples are lacking.

By the end of the third growing season in eastern Australia the 2+ age group has attained a mean length of 73 cm in "good" growing years (see Section V for full discussion), with a mean weight of 17 lb.

By the end of the fourth growing season in eastern Australia the 3+ age group has attained a mean length of 83 cm, with a mean weight of 25 lb.

Thereafter too few fish are caught by trolling in south-eastern Australia to enable us to use the modes in a length frequency distribution for distinguishing size or age groupings. It appears that most of the 4+ and succeeding age groups vacate the inshore areas along the eastern Australian coast in which trolling is now carried on. This is not the case, however, in South Australia and the eastern portion of the Great Australian Bight, where fish up to 60 lb or so are frequently caught by trolling. However, sufficient sampling has not been carried on in those areas to analyse the length frequency composition of these larger fish.

V. VARIATIONS IN THE GROWTH RATE

Both in eastern and in Western Australia fluctuations in the growth rates of immature southern bluefin tuna have been evident during the period we have conducted our surveys, these fluctuations being apparently of greater amplitude in the east than in the west. The growth rates recorded in the preceding section are applicable to "good" growing seasons such as the summer of 1938-39 in the east, but the departures from them were often striking.

In Tables 2-7 are given the measurements of samples of southern bluefin measured by the *Warreen* staff and other cooperators along the eastern Australian coast from southern New South Wales to Tasmania. It is from these data that the graph of growth rates in Figure 3, showing the progression of the means or modes, or both, was plotted, the curves for the successive years 1938-1942 being superimposed.

Table 2

LENGTH MEASUREMENTS OF SOUTHERN BLUEFIN TUNA SPAWNED IN 1934-35

Date	Mean Length (cm)	Number in Sample	*S*	C.V.	Measured by
12.v.1938–4.vi.1938	84·0	50			M. Blackburn
15–25.x.1938	82·0	24			M. Blackburn
8–24.i.1938	86·5	2			D. L. Serventy

Owing to interruptions in the marine programme it was impossible to obtain a continuous series of measurements, and cooperators at shore establishments were not always able to fill in the gaps. With difficulties resulting from World War II no data at all were forthcoming after April 1942. All the samples are given and it will be seen that there is some irregularity in the progression of the means; in some cases, even, the fish stocks appear to become smaller with time! This may be due to the larger individuals of the particular size group passing out of the sampling area, resulting in the lowering of the mean. An alternative explanation may be that these fish tend to school by size as well as by age and then the situation

Table 3

LENGTH MEASUREMENTS OF SOUTHERN BLUEFIN TUNA SPAWNED IN 1935-36

Date	Mean Length (cm)	Number in Sample	*S*	C.V.	Measured by
12.v.1938–4.vi.1938	69·7	17			M. Blackburn
28.vii.1938–5.viii.1938	70·4	12			M. Blackburn
11–28.x.1938	67·9	21			M. Blackburn
23–28.xi.1938	72·5	27			D. L. Serventy
8–24.i.1939	73·5	12			D. L. Serventy
8–15.iv.1939	83·1	2			J. A. Tubb
11–16.v.1939	84·5	48			T. Webb
3–10.vi.1939	83·7	167			J. A. Tubb
13–20.vi.1939	85·9	202			J. K. Newbold
27.vi.1939–18.vii.1939	85·2	219			J. K. Newbold
7.viii.1939	81·9	33			J. K. Newbold
24.viii.1939–5.ix.1939	84·0	19			G. Clark

just discussed may be the result of random variation in sampling. However, despite incompleteness and irregularities in the sampling, some interesting general conclusions are possible.

Season 1938-39.—It will be seen that growth rates for both the major age groups were high in the summer of 1938-39, and the trends of the curves suggest that the situation in the preceding summer, 1937-38, was not markedly different. In 1938-39 the 2+ age group was able to increase in mean length from about 53 to about 73 cm, and in 1937-38 to about 70 cm. The 3+ age group in 1938-39 grew from about 70 to about 86 cm; in 1937-38 it had grown to about the same mean size.

TABLE 4

LENGTH MEASUREMENTS OF SOUTHERN BLUEFIN TUNA SPAWNED IN 1936-37

Date	Mean Length (cm)	Number in Sample	*S*	C.V.	Measured by
2.xi.1938	53·0	14			M. Blackburn
12–18.xi.1938	53·5	43			D. L. Serventy
27.xi.1938–13.xii.1938	54·3	47			D. L. Serventy
8–24.i.1939	55·5	2			D. L. Serventy
9.ii.1939	59·8	6			D. L. Serventy
24.viii.1939–5.ix.1939	73·0	44			G. Clark
4–17.x.1939	73·7	123			D. L. Serventy
8–12.x.1939	72·6	110			C. E. Wellings
26.x.1939–16.xi.1939	72·2	345			D. L. Serventy
15–30.xi.1939	71·3	34			C. E. Wellings
25.xi.1939	72·6	8			D. L. Serventy
21–26.xii.1939	70·0	6			G. Clark
3.iii.1940	81·2	7			J. K. Newbold
1–6.iv.1940	83·5	4			J. K. Newbold
12–19.iv.1940	85·0	38			J. K. Newbold
22–28.iv.1940	84·4	17			J. K. Newbold
5–9.v.1940	86·3	71			J. K. Newbold
10–16.v.1940	86·6	77			J. K. Newbold
21–27.v.1940	86·5	11			J. K. Newbold
3–10.vi.1940	85·2	30			J. K. Newbold
11–15.vi.1940	84·5	27			J. K. Newbold
22–28.vi.1940	86·5	9	4·82	5·57	J. K. Newbold
27.vi.1940–8.vii.1940	86·1	11			G. Clark

Season 1939-40.—However, in the succeeding season, 1939-40, though the 3+ age group experienced a growth rate equivalent to, or even better than, that attained by the similar groups in the previous two summer seasons (it grew from 73 to slightly over 86 cm) the 2+ age group suffered a remarkable retardation. Instead of reaching a mean length in the vicinity of 70 cm (and a mean weight of 17 lb) as in the previous good seasons, it averaged only 64 cm in length (and a weight of slightly over 12 lb) at the end of the growing period. An interesting feature was that the unaffected 3+ age group was almost absent from the inshore

TABLE 5

LENGTH MEASUREMENTS OF SOUTHERN BLUEFIN TUNA SPAWNED IN 1937-38

Date	Mean Length (cm)	Number in Sample	*S*	C.V.	Measured by
24.x.1939	54·6	23			D. L. Serventy
26.x.1939–1.xi.1939	53·9	8			D. L. Serventy
15–29.xi.1939	57·2	344			C. E. Wellings
25.xi.1939	58·5	5			G. Clark
1–11.xii.1939	56·5	129			C. E. Wellings
21–26.xii.1939	55·1	36			G. Clark
30.i.1940–4.ii.1940	55·9	25			G. Clark
12–21.ii.1940	60·7	42			G. Clark
15–21.iii.1940	61·2	85			J. K. Newbold
1–6.iv.1940	61·9	23			J. K. Newbold
12–19.iv.1940	63.0	16	2·42		J. K. Newbold
22–28.iv.1940	62·9	16	1·26		J. K. Newbold
5–9.v.1940	63·4	74	1·64	2·61	J. K. Newbold
10–16.v.1940	64·9	141	2·30	3·57	J. K. Newbold
6–25.v.1940	61·3	28	1·96	3·22	G. Clark
3–10.vi.1940	65·8	22	3·18	4·84	J. K. Newbold
11–15.vi.1940	66·3	120	2·84	4·28	J. K. Newbold
22–28.vi.1940	65·7	68	2·74	4·17	J. K. Newbold
13.vi.1940–8.vii.1940	63·6	58			G. Clark
4–9.vii.1940	66·7	20			J. K. Newbold
16–23.vii.1940	64·7	43			J. K. Newbold
24.vii.1940–2.viii.1940	63·7	10			J. K. Newbold
19.viii.1940–2.ix.1940	64·4	40	2·26	3·51	G. Clark
25–27.ix.1940	64·4	47			D. L. Serventy
2–6.x.1940	64·1	42			D. L. Serventy
12–13.x.1940	64·8	86			D. L. Serventy
25.x.1940	64·5	67			M. Blackburn
1–6.xi.1940	66·1	42			*Warreen*
13.xi.1940	66·3	28			*Warreen*
19–21.xi.1940	67·5	40			*Warreen*
28–29.xi.1940	68·2	5			*Warreen*
12–19.xii.1940	67·3	4	2·93	4·36	*Warreen*
21.i.1941	72·3	13	2·00	2·77	J. K. Newbold
3.ii.1941	71·4	27	2·86	4·01	J. K. Newbold
4–7.ii.1941	70·9	57	2·07	2·92	J. K. Newbold
17–28.ii.1941	72·9	113	1·66	2·28	J. K. Newbold
1–7.iii.1941	72·3	62	1·89	2·61	*Warreen*
5–9.iii.1941	73·4	141	2·07	2·82	J. A. Tubb
11–16.iii.1941	74·2	149	2·34	3·15	J. K. Newbold
11–13.iii.1941	72·9	87			*Warreen*
25.iii.1941–2.iv.1941	75·2	63			*Warreen*
28.iii.1941	75·0	136	2·09	2·8	J. K. Newbold
31.iii.1941–4.iv.1941	75·6	145			J. K. Newbold
5–6.iv.1941	76·0	51			*Warreen*
6–10.iv.1941	77·1	39	1·42	1·8	J. K. Newbold

TABLE 5 (*Continued*)

Date	Mean Length (cm)	Number in Sample	*S*	C.V.	Measured by
13–22.iv.1941	76·6	94			T. Webb
15–22.iv.1941	79·3	14			J. K. Newbold
25–28.iv.1941	77·0	31			*Warreen*
7–11.v.1941	76·9	20			*Warreen*
16.v.1941	77·8	12			J. K. Newbold
17–20.v.1941	80·5	23			*Warreen*
31.v.1941–8.vi.1941	77·9	19			*Warreen*
2.vi.1941	81·5	6			J. K. Newbold
22.vi.1941	80·7	5			*Warreen*

grounds and was not taken at all in the New South Wales spring fishery this season. We do not know where they were but evidently they had avoided the deleterious conditions which affected the 2+ age group, which remained in the south-east area most of the growing season.

Season 1940-41.—In the summer (growing) season of 1940-41 the retarded 2+ age group of 1939-40, now the 3+ age group, was able to recover much of its loss and it had almost reached the "good" growth average for its group—one sample recording a mean length of 81·5 cm. The 2+ age group grew normally during 1940-41 and attained a mean length and weight at the end of the growing season equivalent to that reached in the 1938-39 season.

Season 1941-42.—However, in this season, for which unfortunately complete data are lacking owing to the war interruptions, it appeared that both the 2+ and 3+ age groups suffered retardation in growth. From the data available, the 2+ age group appears to have been as stunted as in 1939-40.

Season 1942-43.—With the *Warreen* not operating on pelagic fish investigations owing to its absence on war work our information was wholly dependent on fishermen's catches. This was an extremely poor season for southern bluefin and very few were caught, but some conclusions as to growth rates are possible from fish sampled at the start of the following season. These suggested that the 2+ age group had suffered some retardation of growth, reaching only a mean length of 68 cm and a weight of 14·4 lb at the end of the growing period.

Season 1943-44.—Samples of fishermen's catches and those obtained from the F.R.V. *Liawenee* in Tasmania showed that the 2+ age group was stunted so severely during the summer growing period that it reached a record "low"; the mean length was 64 cm and the mean weight about 11 lb. The 3+ age group, however, was unaffected and a sample in April 1944 measured 88 cm.

Season 1944-45.—From the scanty data available it was established that the growing season for the 2+ age group was a good one and at the end of the season the mean length was about 72 cm and the mean weight 16·4 lb.

Seasons 1945-46 *and* 1946-47.—No data.

Season 1947-48.—From the meagre details available the growing season for the 2+ age group was satisfactory, a mean weight of 16·7 lb being reached, according to one sample weighed but not measured.

Season 1948-49.—A sample of the 2+ age group measured and weighed at the end of the growing season indicated a good growth rate, the fish reaching a mean length of 72 cm and a weight of 17·2 lb.

TABLE 6

LENGTH MEASUREMENTS OF SOUTHERN BLUEFIN TUNA SPAWNED IN 1938-39

Date	Mean Length (cm)	Number in Sample	*S*	C.V.	Measured by
2.x.1940	53·86	3			D. L. Serventy
25.x.1940	53·95	2			M. Blackburn
13–14.xi.1940	57·1	10			*Warreen*
19–29.xi.1940	57·44	17			*Warreen*
18–19.xii.1940	58·72	9			*Warreen*
22.vi.1941	72·14	18			*Warreen*
29.viii.1941	72·24	68			W. C. McKinnon
9.ix.1941	72·4	64			W. C. McKinnon
15–17.ix.1941	71·5	270			W. C. McKinnon
15.ix.1941–2.x.1941	71·6	498			W. C. McKinnon
23.ix.1941	70·2	23			G. Clark
21.ix.1941	69·7	128			W. C. McKinnon
5–13.x.1941	73·3	79			*Warreen*
21–31.x.1941	72·2	1478			W. C. McKinnon
6–16.xi.1941	71.4	45			*Warreen*
23.xi.1941–2.xii.1941	67·7	53			M. Blackburn
12–15.xii.1941	69·2	4			D. L. Serventy
23.ii.1942	71·85	61			J. K. Newbold
20.iii.1942–2.iv.1942	73·98	19			J. K. Newbold
28.iii.1942	72.1	3			H. M. Peddie

Season 1949-50.—The growing season for the 2+ age group was an unfavourable one and the fish reached only a mean length of 67 cm and a mean weight of about 13 lb.

Season 1950-51.—No data.

Thus, summarizing, we have had the following succession of growth seasons for the 2+ age group:

1937-38, good; 1938-39, good; 1939-40, retarded; 1940-41, good; 1941-42, retarded; 1942-43, retarded; 1943-44, very retarded; 1944-45, good; 1945-46, no data; 1946-47, no data; 1947-48, good; 1948-49, good; 1949-50, retarded; 1950-51, no data.

Thus out of 14 successive seasons six were good growing years for this age group, five were poor years, and for three years no data are available. The commercial implications of this fluctuation are highly important, as this group, when it re-enters the New South Wales spring fishery as the 3+ age group, is the predominant size group of southern bluefin caught by trolling in the present-day inshore grounds. It will be noted that a retarded growth rate in any particular summer has a repercussion on the fishery during the succeeding spring.

TABLE 7

LENGTH MEASUREMENTS OF SOUTHERN BLUEFIN TUNA SPAWNED IN 1939-40

Date	Mean Length (cm)	Number in Sample	*S*	C.V.	Measured by
14.xi.1941	54·5	4			D. L. Serventy
25.xi.1941–2.xii.1941	53·1	9			M. Blackburn
12–15.xii.1941	55·7	11			D. L. Serventy
5.iii.1942	62·2	69			C. E. Wellings
28.iii.1942	59·8	2			H. M. Peddie

VI. DISTRIBUTION OF THE SIZE GROUPS

A summary of the seasonal movements of this species in Australian waters has already been given (Serventy 1941*a*, p. 29). As far as south-eastern Australia is concerned this account needs no amendment.

The western limit of this eastern population appears to be Port Phillip Bay and the chain of islands from Wilson's Promontory to the Furneaux group. Southern bluefin tuna are practically never caught in the central and western portions of Bass Strait. This has been the experience of the Division's research vessels and is corroborated by Mr. W. H. Nicholls, formerly of Three Hummock Island. He has never taken these tuna in the western sector of the strait.

The youngest southern bluefin yet observed in the eastern area are members of the 1+ age group at the end of the second winter non-growing period, and approaching 2 years of age. The fish, which are 6-8 lb in weight, are now virtually at the beginning of their third growing season and, as previously explained, may conveniently be referred to as the 2+ age group. They are first reported on the New South Wales coast at various points between Eden and Sydney, about the beginning of October. As the season progresses they travel southwards, usually becoming abundant at Eden in November. Thence they follow the coast around to Westernport Bay, Vic., and beyond, sometimes reaching Port Phillip Bay, and then moving across Bass Strait to Tasmania. They reach their maximum concentration in Victorian waters between January and March (Serventy 1941*b*, p. 1).

Some shoals appear to pass directly to Tasmania, though in some years they apparently are not found in any numbers in inshore waters in Tasmania at all, as was the case in the seasons 1938-39 and 1940-41 (Serventy 1947, p. 142).

About July or August they begin to reappear in the Flinders Island region and the south-eastern Australian coast, moving northwards towards Sydney. They may then be referred to, as previously discussed, as the 3+ age group, and are of a mean size, varying according to the character of the preceding growing season, from 11 to 17 lb. The northernmost point reached during October also varies according to the season and may be anywhere between Eden and Sydney. The main centre of occurrence, in ordinary years, between September and November, is between Cape Everard and Jervis Bay and this size group is the predominant one in the inshore fishery in most years. With the continuance of the southward movement New South Wales waters may be entirely vacated by December, but the vanguard of the shoals may already be in south Tasmanian waters by October. They stay in the south for the remainder of the summer, autumn, and early winter, though they go further afield in the midsummer period.

They reappear in southern New South Wales waters the following season as the 4+ age group and at an average weight, as already stated, of about 25 lb. They repeat their previous year's cycle but do not, as a rule, travel as far north up the coast and also leave for the south again rather earlier. Their relative numbers in the area vary considerably and in some seasons they may supplant the 3+ age group as the predominant group in the fishery. This appeared to have been so in the spring of 1936, if one may judge by the sports anglers' records (Lyne 1936) and was certainly so in the spring of 1946. After completing the season the fish behave differently, and henceforth are no longer met with in inshore waters of the eastern States, except odd individuals still mingling with the immature shoals.

Figure 4, based on "catch per unit of gear" data, shows the relative frequencies of the various age groups along the New South Wales coast.

A similar cycle takes place in South Australia. Fish of the 2+ age group appear in the region of Backstairs Passage about November, sometimes earlier, and then deploy into St. Vincent and Spencer Gulfs. Not much is known of their movements at the onset of winter but they reappear again off Backstairs Passage in the early summer as both the 3+ and 4+ age groups. After that they tend to disappear from the local inshore fishery just as in south-eastern Australia. However, the 4+ age group is particularly plentiful on the eastern side of the Great Australian Bight, in inshore waters, together with older fish, probably of the 5+ age group. An analogous concentration of such "large immatures" and "sub-adults" has not yet been located in the south-eastern Australian sector. Mr. W. H. Nicholls has reported fish up to 60 lb in weight on the western side of King Island, and these are almost certainly of the South Australian stock.

In Western Australia the situation is rather different from that in both South Australia and south-eastern Australia. It has already been stated that extremely young fish may be captured in southern Western Australia within, presumably, a few months of spawning, and that both the 0+ and 1+ age groups, but rarely any older fish, comprise the local troll fishery. The 0+ age group has been taken from the Archipelago of the Recherche in the east to the region of Shark Bay (lat. 25° 30′ S.) in the north, and from February to November. The 1+ age group has been caught only as far north as Jurien Bay (lat. 30° S.) and occurs eastward to the Great Australian Bight. Immature fish of larger size have been infrequently taken in south-western Australia, but are most commonly met with in the neighbourhood of the Recherche Archipelago. However, in the autumn of 1951 the 2+ age group, for the first time during the present investigation, appeared in some strength along the south coast in the vicinity of Albany, though they were numerically inferior to the younger groups. They first appeared in late March, at a mean length of about 65 cm and mean weight of 13 lb, and gradually tapered off in numbers by July. Odd individuals of the 3+ age group were mingled with them. A record of the presence of fish of the 2+ age group in inshore waters is available from 1937; in January of that year a fish of that size group was netted 3 miles up the Frankland River, Nornalup (John Gregory, unpublished data).

VII. ADULT SOUTHERN BLUEFIN IN AUSTRALIA

(*a*) *Western Australia*

Reference is made in Section VIII to the location and period of occurrence of spawning adults in Western Australia, which have been reported around the south coast in the vicinity of Albany. Thus far observations of such fish have only been reported from Frenchman Bay to Cheyne Beach. The heaviest fish caught so far in this region weighed 310 lb (estimated), and 200-300 lb fish are common.

Large specimens, up to 250 lb, are also met with in the Geographe Bay region, where they have also at times been captured on the shark long lines. The following cases are on record:

(i) A specimen estimated at 100 lb, taken on shark long lines off Bunbury on November 25, 1944.

(ii) A large specimen, 6 ft 4 in. in *total* length and 250 lb in weight, washed ashore at Dunsborough on January 18, 1946.

(iii) A large specimen over 5 ft in length and estimated to be between 200 and 250 lb in weight, netted at Busselton on February 24, 1946.

(iv) A specimen 52½ in. in length, caught on shark long lines off Bunbury on February 15, 1949.

A sight observation of large tuna, of possible significance concerning the distribution of this species, was made by R. G. Chittleborough and E. H. M. Ealey, biologists of the Australian National Antarctic Research Expedition, when returning from Heard Island in H.M.A.S. *Labuan* on March 9, 1950. In lat. 38° 21′ S., long. 111° 33′ E., a "school of over a dozen tuna were sighted at 1330 hours, well to starboard (watched through glasses). They were at least six feet in length, leaping almost right out of the water, though not simultaneously. The nearest land was Cape Leeuwin, 300 miles N.E." (*in litt.*).

(*b*) *South Australia and Adjacent Waters*

Though fish between 40 and 90 lb are frequently caught in South Australia, particularly in Investigator Strait and the eastern part of the Great Australian

Bight, larger specimens equivalent to the Western Australian adults have come under notice only sporadically. The following records have been traced:

(i) Portland, Vic., date not known; length to the caudal fork, 5 ft 10 in. (= 178 cm); specimen in National Museum of Victoria and referred to by McCoy (1880, p. 22).

(ii) Glenelg, S.A., date not known; stranded some time prior to 1890, record based on a drawing of a specimen reputed to have weighed 800 lb, in the collection of the South Australian Fisheries and Game Department. If correct this is the greatest weight so far known of an Australian specimen of the species.

(iii) No locality, date not known; the South Australian Museum possesses a mounted specimen of a length to the caudal fork of 140 cm and estimated to have weighed 150 lb.

(iv) Off Port Lincoln, S.A., April 1936; 135 lb. Caught on sports tackle by D. W. Taylor.

(v) Semaphore Beach, St. Vincent's Gulf, S.A., May 2, 1945; 116 lb, length to the caudal fork 144 cm, ♀, probably recently spawned. Specimen preserved in South Australian Museum.

(vi) C. de Couëdie, Kangaroo I., S.A., March 1946; 108 lb. Hand-lined by T. Ticklie (*in litt.*, L. V. Hannan).

(*c*) *Eastern Australia*

There are several records of very large individuals from the eastern coastline. The following is a summary:

(i) Spring Bay, Tas., 1869; no date, probably during the month preceding November 16; specimen over 400 lb driven ashore and tail presented to the Hobart Museum (*Pap. Roy. Soc. Tasm.* **1870**: 47).

(ii) Port Hacking, N.S.W., in June 1907, and a few days later at Port Jackson; "an exceedingly large shoal of great tunnies", one of which (139 lb) was harpooned and cast made for the Technological Museum, Sydney (Stead 1907, p. 392; Roughley 1916, p. 164).

(iii) Bicheno, south-eastern Tasmania, 10 miles offshore, March 5, 1937; a huge shoal of very large fish seen from aeroplane by S. Fowler (*in litt.*, April 24, 1940).

(iv) Bermagui, N.S.W., May 1937; 238 lb, specimen caught by T. A. Bell (1937, p. 5, illus.).

(v) Port Kembla, N.S.W., May 1937; 85 lb fish caught by A. L. Caselberg (1937, pp. 17, 25, illus.).

(vi) Wollongong, N.S.W., 23 miles reef, October 22, 1938; Caselberg (1938, p. 3) saw a school of what he took to be 150-300 lb tuna.

(vii) Off Gabo I., 1939, before the winter; E. Cole of Eden reported a number of large tunny "quite 6 or 7 feet in length", (*in litt.* C. E. Wellings, March 16, 1940).

(viii) Tasman's Passage, near Cape Pillar, Tas., end of April 1946; 125 lb specimen caught by B. T. Cuthbertson.

(ix) Fortescue Bay, Tas., May 5, 1947; 101 lb specimen caught by B. T. Cuthbertson.

(x) Jervis Bay, N.S.W., 20 miles offshore, October 16, 1950. The American tuna clipper *Senibua* encountered large tuna, estimated to weigh between 150 and 200 lb; none were caught but the fish could not be landed by three-pole fishing teams (Roughley 1951, p. 209).

These records demonstrate that large bluefin do travel the east coast and on rare occasions come sufficiently close inshore, or to the surface, to be observed and captured.

The interesting feature about most of these records and reports for both South Australia and south-eastern Australia is that they were made in the late summer and autumn months, and there is a distinct suggestion that the movement is northwards at this season. The remaining records are from October, and these might possibly be indicative of a return movement.

Apart from the positive records enumerated there is quite a crop of anecdotal and unverifiable reports on the movements of large tuna off the coast. The following from the Division's file is an example: "This boatman tells me that last year, while coming down from Ulladulla to Bermagui . . . he ran into big blue tuna which he estimated to be between 200 lb and 800 lb in weight. The inside edge of them was about 12 miles offshore. He steamed seaward for 6 or 7 miles and as far as he could see seaward, these fish were still visible on the surface crashing among schools of pilchards. All the way south to Bermagui, he steamed through what he described as almost a solid mass of big tuna.".

VIII. Spawning Season

Neither the peak nor the duration of the spawning season is yet known but large adults in near spawning condition may have been observed in the Albany area, where at times they may enter the shallow waters of the inner harbour in considerable numbers (Serventy 1941*a*, p. 31). Their first appearance may be as early as the end of September but is more frequently at the end of October. They are seldom seen after March, though they have been observed at times as late as the end of April. None of the fish during this period will take the hook though sports anglers have tried a variety of gear on repeated occasions. This disinclination to take the hook is characteristic of the European *Thunnus thynnus* at the spawning season (cf. Russell 1934*a*, p. 641), and it may be inferred that the months mentioned, i.e. late September to March, represent the span of the spawning period of the species in Western Australia. All of the specimens captured by nets at this period have enormously developed gonads and I have personally examined two specimens taken as late as early March which had not yet spawned. No fish in an actual spawning state has yet come under observation and it would seem likely that such individuals vacate the immediate inshore waters and shallows at that time.

The following data are available on specimens examined in near spawning condition:

(i) Albany Harbour, W.A., March 3, 1939; weight 110 lb; ♀, weight of ovaries 255 g (= 0·5 per cent. of body weight).

(ii) Albany Harbour, March 3, 1939; weight 264 lb; ♂, weight of testes 1358 g (= 1·1 per cent. of body weight).

(iii) Albany Harbour, January 1, 1941; weight 191 lb; ♂, weight of testes 1254 g (= 1·5 per cent. of body weight).

(iv) Albany Harbour, January 1, 1941; weight 175 lb; ♀, weight of ovaries 650 g (= 0·8 per cent. of body weight).

(v) Albany Harbour, January 1, 1941; weight 204 lb; ♀, weight of ovaries 1270 g (= 1·4 per cent. of body weight).

(vi) St. Vincent's Gulf, S.A., May 2, 1945; 116½ lb; weight of ovaries 218 g (= 0·4 per cent. of body weight). This specimen, which was found stranded on the beach, was examined by Dr. K. Sheard and considered to have only recently spawned.

It appears that specimens under 100 lb in weight are immature. Records of the maturity condition of the few individuals caught approaching this size are as follows:

(i) Investigator Strait, S.A., February 23, 1939; 62½ lb, L.C.F. 114 cm; ♂, weight of testes 20 g; trolled by *Warreen*.

(ii) Anxious Bay, S.A., April 30, 1947; 78 lb, L.C.F. 121 cm; ♀, weight of ovaries 50 g; trolled by *Warreen*.

(iii) C. Catastrophe, S.A., April 30, 1949; 60 lb, L.C.F. 116 cm; ♀, weight of ovaries 70 g; trolled by *Warreen*.

(iv) C. Catastrophe, S.A., February 23, 1949; 91 lb, L.C.F. 129 cm; ♂, weight of testes 85 g; trolled by *Warreen*.

No eggs or larvae of this tuna have so far been identified in Australian seas. Young fish, presumably a few months old, have been taken only in south-western Australia. The earliest in date was one caught at Bunbury on February 29, 1944, by Fisheries Inspector J. Goodlad, which weighed 1½ lb and measured 33·7 cm (= 13¼ in.) in length (snout to the caudal fork). Another, the smallest so far collected, was trolled by the *Warreen* south of Albany on March 25, 1951, and weighed 1 lb 5 oz, and measured 31·8 cm (= 12½ in.) in length.

Thus the evidence so far proves the existence of only one spawning ground in Australia, off the south-west corner.

IX. NUMBER OF BREEDING STOCKS

I have previously suggested (Serventy 1941*a*, p. 30) that there were two separate spawning stocks of southern bluefin in Australia, that the immature fish which used eastern Australia (New South Wales, Victoria, and Tasmania) as a nursery ground were distinct from the immature fish which used the gulfs of South Australia as a nursery ground. The evidence in favour of this view may be set out as follows.

(*a*) There is no geographical continuity of distribution between the South Australian and south-eastern Australian fish. Southern bluefin tuna are rare or absent in western Bass Strait, west of Port Phillip Bay and the Wilson's Promontory-Furneaux Is. chain of islands. The fish taken at Portland, Port Fairy, and on the western side of King Island appear to represent the extreme fringes of the South Australian population.

(*b*) Because of this geographical discontinuity the statistically significant differences in certain body proportions (Table 1) may be interpreted as evidence of separate breeding grounds for the South Australian and eastern Australian fish. The characters referred to are the head length in relation to body length, the depth of body, the relative position of the second dorsal fin along the body, the length of the pectoral fin, and the length of the maxillary.

(*c*) The small 2+ age group appears in New South Wales and in South Australia at approximately the same time each spring and early summer, and there is a wide geographical gap between them. They appear to be two independent irruptions from widely separated origins.

The relations between the Western and South Australian fish are not so clear. The following considerations would suggest that there is only one spawning stock involved:

(*a*) There is a continuity of distribution of individuals across the Great Australian Bight.

(*b*) In Western Australia usually only the 0+ and 1+ year age groups occur. The 0+ age group is missing in South Australia, where the 2+ and older sub-adults predominate. The inference would be that the fish move progressively eastwards from the spawning area as they grow older. Some portion of the 1+ age group, which forages in South Australia, must grow at a slower rate than Western Australian members of the age group to account for the difference in size mentioned in Section IV.*

There are, however, significantly different morphometric characters between the Western Australian and South Australian fish (Table 1). These are not so extensive as between the South Australian and eastern Australian fish, but, of the characters measured, the following differ between the South Australian and the Western: the length of the pre-opercular, the lengths of the second dorsal, anal, and pectoral fins, and the position of the ventral fin and the vent. These differences are not necessarily diagnostic of separate spawning stocks—they could exist as differentiations at the extremes of a connected breeding population. However, taken in conjunction with the differences in mean size of the 1+ age group in South and Western Australia, the reality of separate spawning populations becomes more probable. These two bodies of fish apparently intermingle.

The relation of the eastern Australian and Tasmanian stock to the large adults found at times in New Zealand is quite unknown at present. It may quite well be that they belong to one and the same breeding group.

* This phenomenon of a faster growth rate in southern Western Australian waters than in South and south-eastern Australia is exhibited by other fish species, including the gummy shark, *Mustelus antarcticus* Günther; Australian salmon, *Arripis trutta* (Bloch & Schneider); King George whiting, *Sillaginoides punctatus* (C. & V.); and sweep, *Scorpis georgianus* (C. & V.). It has been studied in detail only in *Arripis trutta*.

X. FLUCTUATIONS IN ABUNDANCE AND OTHER SEASONAL VARIATIONS

Reference has already been made to the marked seasonal fluctuations in growth rate among immature southern bluefin in south-eastern Australia. There are also other characteristics of the tuna in this region which exhibit marked differences between one year and another and which will have an important bearing on the economics of any fishery which may later develop on the species. These seasonal variations appear to have a much more severe amplitude in south-eastern Australia than either in South Australia or in Western Australia. These fluctuating features may be more particularly referred to here.

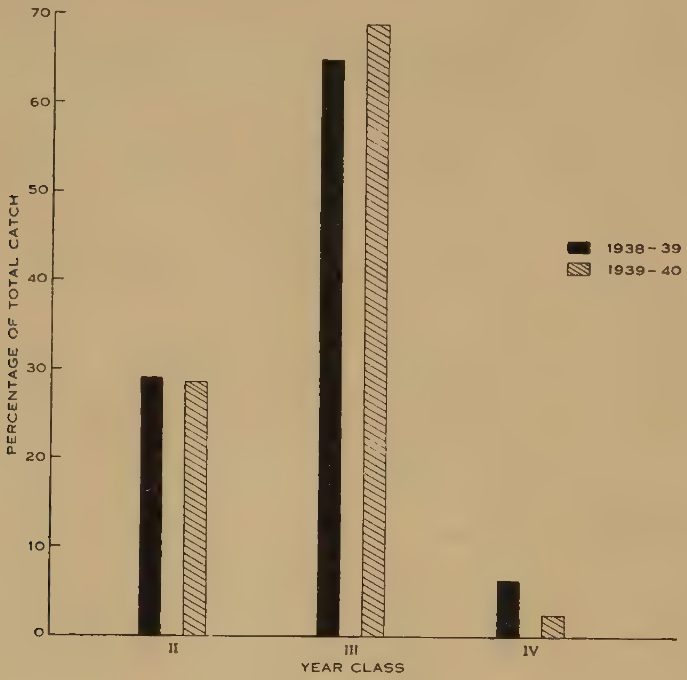

Fig. 4.—Age composition of the *Warreen*'s catches, 1938-39 and 1939-40 seasons, expressed as percentages of the season's total catch: south-eastern Australia.

(*a*) *Variations in the Growth Rate*

The considerable variations in the growth rate of the 2+ and 3+ age groups have been treated in detail in Section V.

(*b*) *Variations in the Proportions of the Age Groups*

The relative proportions of the three age groups which are operated on by the present tuna fishery in eastern Australia are distinctly different from their proportions in the South Australian catches. The differences for the two seasons 1938-39 and 1939-40 are illustrated in the accompanying graphs (Figs. 4 and 5; see also Fig. 9). Curious disparities in the expected proportions of the age groups are at once evident. One would expect a comparatively large number of the younger fish, and then a gradual tapering off in numbers due to natural mortality—assuming, of course, no great variation in the strength of the age groups and no selectivity by the catching gear. This tapering off is actually what the *Warreen* did obtain by trolling in South Australia. Figure 5 shows that the South Australian fish caught were distributed according to normal expectation in the fishing grounds and that therefore the commercial catch in these South Australian grounds may not be far off a true reflection of the actual population; truer, at any rate, than appears to be the case in south-eastern Australia. In the east there is a great preponderance of the 3+ age group (Fig. 4). Similar relations have been found to apply for most years. The 2+ age group is almost always much below the 3+ age group in numerical strength, and in some years may be virtually absent from the New South Wales coast. At times, as apparently happened in 1936 and 1946, the 4+ age group may exceed the 3+ age group in strength.

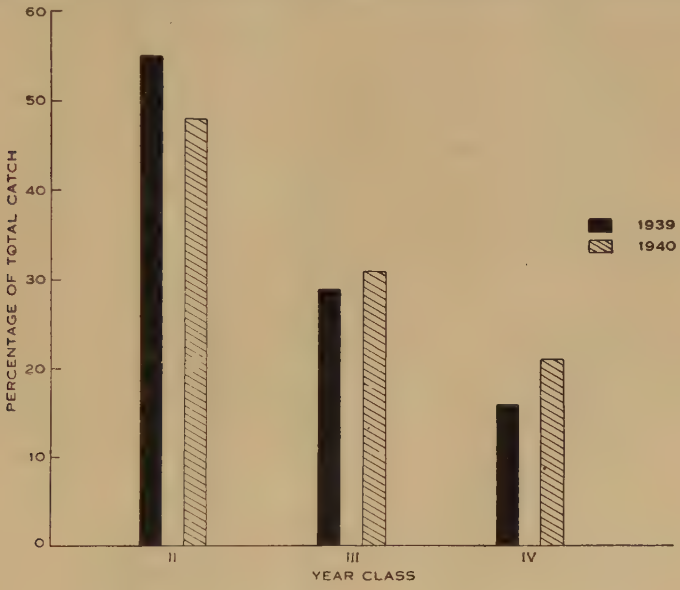

Fig. 5.—Age composition of the *Warreen*'s catches, 1938-39 and 1939-40 seasons, expressed as percentages of the season's total catch: South Australia.

We must assume that in eastern Australia we are not, by the present methods of fishing in the inshore waters, sampling the main centres of concentration of the shoals, as we probably are in South Australia. It seems that in the east we are operating only on the fringes of the species' distribution and that for an effective exploitation of the stocks we have not yet completed the survey of their distribution. This fact, that we are fishing the fringe of the area of occurrence and not the main centres of distribution, may account for the severity of some of the fluctuations met with. In such cases the effects of the fluctuations would be much more severely felt at the limits of the distribution than at the centre.

(c) *Variation in Numbers of Individuals*

There may be marked variation in the availability of fish from year to year even though there may not be much change in the proportionate strengths of the age groups or of the mean sizes of the fish. Thus in the 1938-39 season the *Warreen* trolled for 609 hours and caught 390 fish: in the 1939-40 season the *Warreen* trolled for 606 hours and caught 606 fish. The general area covered was the same; a similar procedure was followed; the duration of trolling was almost exactly the same—yet the total catch in the first season was only 65 per cent. of that of the following one. In 1938, however, fishing started much later in the season.

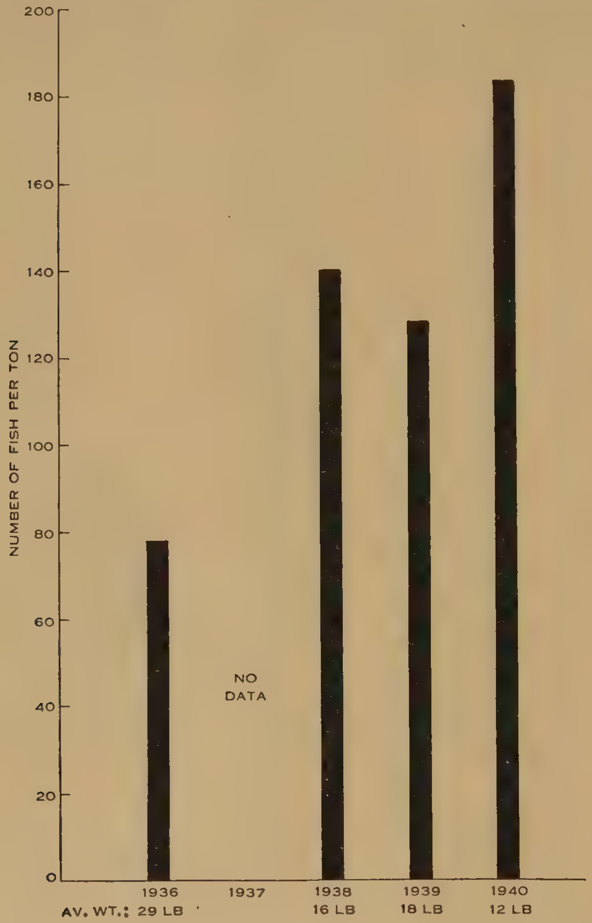

Fig. 6.—Number of southern bluefin to the ton in the New South Wales spring fishery.

Further reference to the fluctuations in numerical abundance is made in Section X(*e*).

The commercial consequences of some of these fluctuations are illustrated graphically in Figure 6. This gives the number of southern bluefin to the ton in the spring fisheries of New South Wales for various seasons between 1936 and 1940. These numbers were computed from analyses of sports fishermen's records and catches of the F.R.V. *Warreen*. There were, for instance, just under 80 fish to the ton in 1936; over 180 in 1940. The graph can be interpreted as a measure of the fishing effort entailed in making an equivalent catch in each season shown. The height of the bars is proportional to the effort which had to be expended in obtaining the same quantity of fish.

TABLE 8

CATCH PER UNIT OF GEAR, NEW SOUTH WALES, 1938-39 SEASON

Period	Hours of Trolling, Sydney Sthward.	Line-hours in Tuna Grounds	Total Catch of Age Groups				Catch per 100 Line-hr			
			2+	3+	4+	Total	2+	3+	4+	Total
10–14.x.1938	25	90	0	13	1	14	0	14·4	1·1	15·6
28.x.1938–2.xi.1938	61½	246	15	14	2	31	6·1	6·1	0·8	12·6
11–19.xi.1938		231	45	0	0	45	19·5	0	0	19·5
28.xi.1938–13.xii.1938		374	49	7	0	56	13·1	1·9	0	15·0
8–24.i.1939		67	4	1	0	5	6·0	1·5	0	7·5
	Total:	1008	113	35	3	151				

TABLE 9

CATCH PER UNIT OF GEAR, NEW SOUTH WALES, 1939-40 SEASON

Period	Hours of Trolling, Sydney Sthward.	Line-hours in Tuna Grounds	Total Catch of Age Groups				Catch per 100 Line-hr			
			2+	3+	4+	Total	2+	3+	4+	Total
24–26.viii.1939		101	0	5	8	13	0	5	7·9	12·9
3–5.ix.1939		99	0	39	7	46	0	39·4	7·1	46·5
2–8.x.1939		183	23	102	6	131	12·6	55·7	3·3	71·6
17.x.1939–6.xi.1939		336	9	118	0	127	2·7	35·1	0	37·8
15–17.xi.1939		125	0	41	0	41	0	32·8	0	32·8
24–25.xi.1939		88	5	8	0	13	5·7	9·1	0	14·8
26–28.xii.1939		96	36	0	0	36	37·5	0	0	37·5
28.i.1940–8.ii.1940		120	22	0	0	22	18·3	0	0	18·3
10–27.ii.1940		141	2	0	0	2	1·4	0	0	1·4
	Total:	1289	97	313	21	431				

These population variations may be considered in greater detail by an analysis of the "catch per unit of gear" records of the *Warreen* along the New South Wales coast between 1938 and 1942. The standard catching gear consisted of four trolling lines which were operated in an approximately consistent manner throughout (Serventy 1941*a*, p. 14). The results make possible the computation of index numbers which could be considered as providing a numerical expression of the varying availability of the southern bluefin during a season and between one season and another.

TABLE 10

CATCH PER UNIT OF GEAR, NEW SOUTH WALES, 1940-41 SEASON

Period	Hours of Trolling, South of Sydney	Line-hours in Tuna Grounds	Total Catch of Age Groups				Catch per 100 Line-hr			
			2+	3+	4+	Total	2+	3+	4+	Total
10–12.vi.1940	60		0	0	0	0	0	0	0	0
16–18.vii.1940		80	0	1	3	4	0	1·3	3·8	5
19.viii.1940–5.ix.1940	1	124	0	40	0	40	0	32	0	32
25–27.ix.1940		100	0	47	0	47	0	47	0	47
2–13.x.1940		265	3	129	0	132	1·1	49	0	49·8
25.x.1940–6.xi.1940		150	0	50	0	50	0	33	0	33·3
13–29.xi.1940		447	27	76	0	103	6	17	0	23·0
18–19.xii.1940		155	10	0	0	10	6·5	0	0	6·5
17–31.i.1941	115	—	0	0	0	0	0	0	0	0
25–28.ii.1941	75	—	0	0	0	0	0	0	0	0
	Total:	1321	40	343	3	386				

TABLE 11

CATCH PER UNIT OF GEAR, NEW SOUTH WALES, 1941-42 SEASON

Period	Hours of Trolling, Sydney Sthward.	Line-hours in Tuna Grounds	Total Catch of Age Groups				Catch per 100 Line-hr			
			2+	3+	4+	Total	2+	3+	4+	Total
22–25.vi.1941	19·5	65	0	17	5	22	0	26·2	7·7	33·8
3–15.x.1941	98·5	217	0	49	6	55	0	22·6	2·8	25·3
5–18.xi.1941	117·5	395	4	45	1	50	1·0	11·4	0·3	12·7
22.xi.1941–4.xii.1941	108·8	321	9	19	0	28	2·8	5·9	0	8·7
10–21.xii.1941	96·8	214	11	4	0	15	5·1	1·9	0	7·0
17–23.iii.1942	29·8	—	0	0	0	0	0	0	0	0
Total:	470·9	1212	24	134	12	170				

The data are summarized separately for each season in Tables 8-11. A record was kept of the duration of trolling on each cruise, and in the tables "line hours" represents the product of the number of trolling lines and the number of hours they were in operation. The "line hours" have been computed only for that section of the coast along which the tuna occurred, and this would vary with the progress of the seasonal migration, as already outlined in Section VI. The catch record of southern bluefin has been subdivided into age groups determined by length frequency analysis. The data represent the catches made during transit on reconnaissance voyages and hence cannot be used directly for the assessment of commercial possibilities. A commercial vessel would concentrate on areas of high tuna density and, once on the grounds, would continue sustained fishing whilst the tuna were biting.

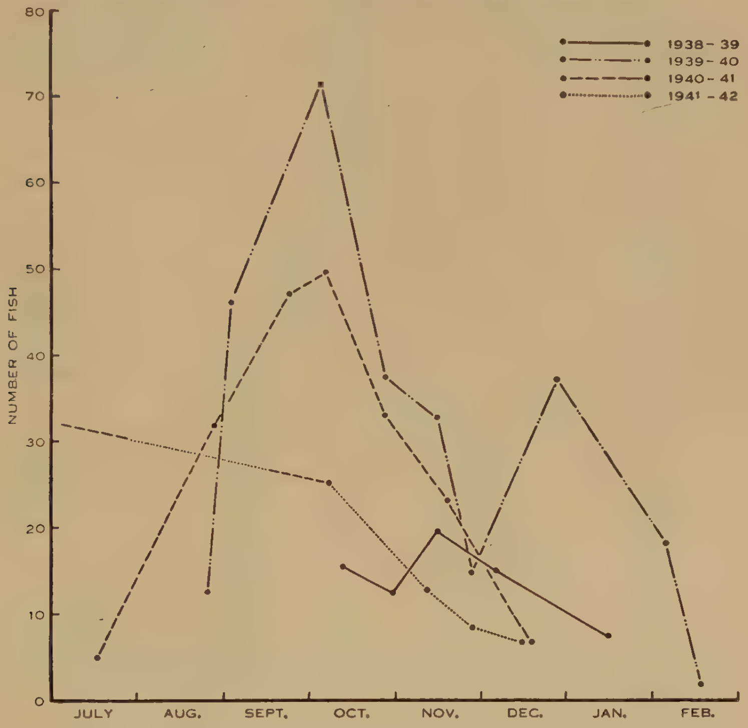

Fig. 7.—Total catches of southern bluefin per 100 line-hours at intervals during various seasons, New South Wales.

Unfortunately owing to various difficulties outside the direct control of the research staff, the *Warreen* was unable to make the planned frequent traverses of the area during the tuna season and serious gaps in the observations occurred, particularly in 1941.

As a measure of the variation in abundance from season to season Serventy (1947, p. 147) employed the season's average "catch per 100 line-hours", for total fish caught, as a numerical index for the interpretation of the tuna trolling tests of 1941. This index was weighted by taking account of the mean weight of all fish caught for the season, to produce a "commercial index".

Figure 7, compiled from these data, shows the total catches of southern bluefin tuna per 100 line-hours during the five fishing seasons sampled by the *Warreen.*

Owing to the fewness of observations the postulated trend of the 1941-42 curve, prior to October, has dubious validity. The graph emphasizes the low population density of the species along the New South Wales coast in 1938-39 and 1941-42 as compared with 1939-40 and 1940-41. The bulk of the fish comprising the normal fishery in this area belongs to the 3+ age group; Figure 8 shows the catch of this group, on a 100 line-hours catching basis, for the four seasons. Figure 9 shows the details of the age groupings of the 1940-41 catch, on the same catch per unit basis, demonstrating the relative abundance of the age classes and their seasonal distribution in New South Wales (referred to in Section X(*b*)).

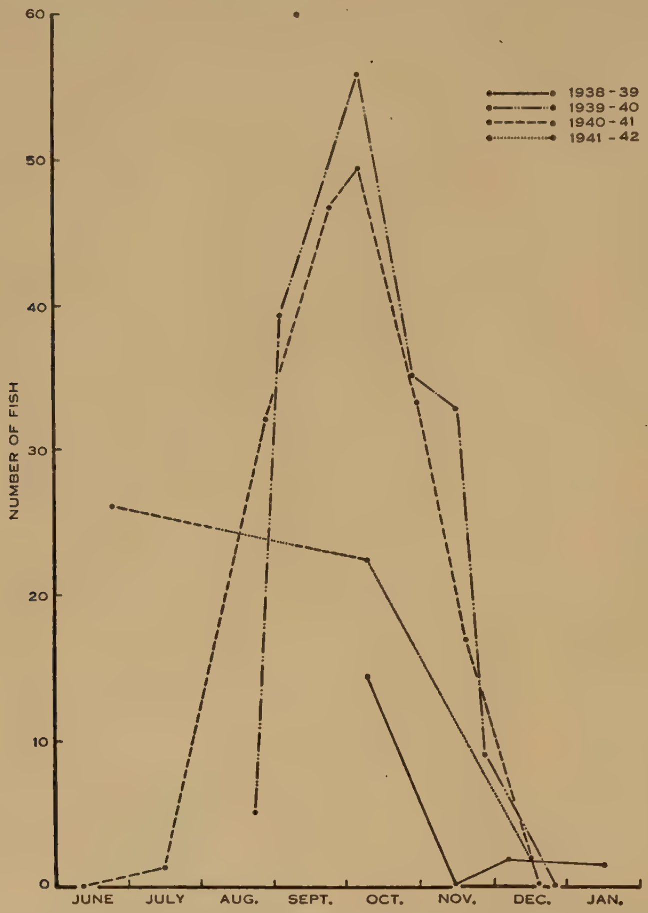

Fig. 8.—Catches per 100 line-hours of southern bluefin of the 3+ age group at intervals during various seasons, New South Wales.

Similar data on catch per unit of gear are available for the operations of the *Warreen* in eastern Bass Strait and eastern Tasmania, but the cruises were less frequent than in New South Wales and the records are, therefore, less satisfactory for detailed analysis. Generally speaking the catch per 100 line-hours is always less in Tasmania than in New South Wales and less still in eastern Bass Strait. The most reasonable interpretation of this is that the fish shoals become dispersed over a wider foraging area after they leave the narrow coastal shelf of New South Wales.

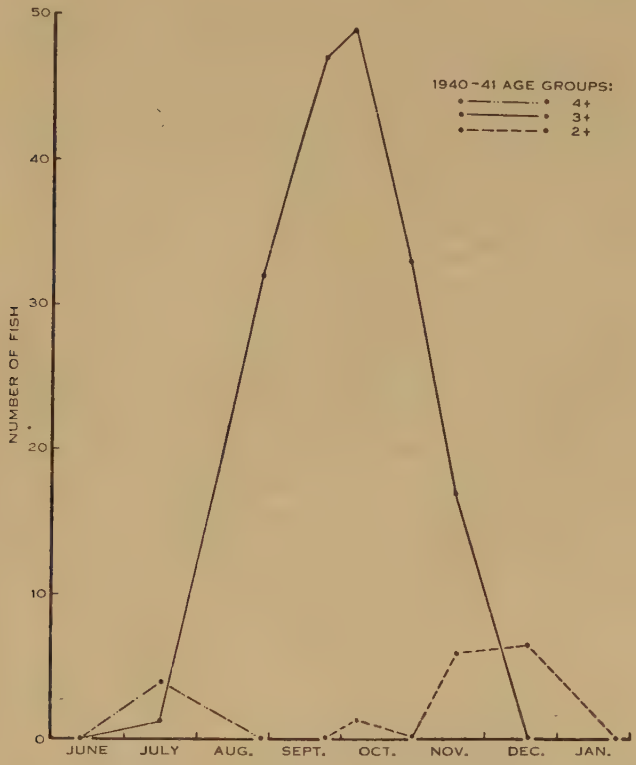

Fig. 9.—Catches per 100 line-hours of southern bluefin divided into age groups, at intervals during the 1940-41 season, New South Wales.

An analysis of the catches of a commercial fishing boat, the ketch *Weerutta*, on a somewhat different basis—catch per day's absence from port—has already been published (Serventy 1947, p. 140, Fig. 1).

A summary of southern bluefin availability in the spring fishery of coastal New South Wales is as follows:

1938	Poor to moderate (cf. Fig. 7).
1939	Very good.
1940	Good.
1941	Poor. In this season a commercial trolling test under the auspices of C.S.I.R.O. was conducted, and one boat during 63 fishing days caught 1042 southern bluefin, weighing 7·8 tons (Serventy 1947).

1942	Very poor.
1943	Apparently good, but positive information for this year and the remainder of the war period is lacking.
1944	Apparently good.
1945	Apparently good, but the season seems to have ended early.
1946	Apparently good, due to abundance of the 4+ year class; the two smaller age classes were not taken in any quantity.
1947	Apparently good.
1948	Apparently good, but details scanty.
1949	Very good. The Narooma cannery received 210 tons of tuna (mostly southern bluefin) during the period August-December, and the bulk of this was received in September.
1950	Poor.
1951	Apparently poor.

(*d*) *Variation in Northward Migration along the Coast*

There is considerable variation in the degree of penetration northwards of the 3+ age group as it migrates up the New South Wales coast each spring. Figure 10 shows the distances travelled in certain years. There seems to be some relation also between the most northerly point reached and the place where the shoals of the incoming 2+ age group first strike the coast (shown by the broad arrow in each diagram). Unfortunately our data are rather fragmentary in several respects and during the war years, when the research vessels were out of commission, it was impossible to get any real information at all bearing on this interesting aspect of the tuna's movements.

It will be seen that in 1938 the 3+ age group did not penetrate beyond Jervis Bay, as far as we could ascertain, and the 2+ age group was first encountered at about Wollongong. In 1939 the 3+ age group travelled as far north as Sydney, which also was the place of first appearance of the 2+ age group; thus far Sydney is the northernmost known limit for the species. In 1940 the limit for the 3+ age group, and the place of first appearance of the 2+ age group, was Jervis Bay. For 1941 our data are defective but the corresponding geographical point for both groups was about Montague Island.

An interesting feature that emerged from this study was that when the southern bluefin season was a "good" one (in the matter of availability, not necessarily of growth rate during the preceding summer) the fish travelled further north along the coast. The greater the numbers the further north was their extension along the coast. The spring fishery of 1939 was the best we had had in the earlier series of observations and the bluefin were taken as far north as Sydney. In 1938 and 1940, when the availability was indifferent, the tuna reached only as far as Jervis Bay. In 1941, a really bad year, tuna were scarce and were not reported north of Narooma. In the phenomenally poor year of 1942 hardly any bluefin were met with at all along the New South Wales coast. For this disastrous season C. E. Wellings, of Eden, reported to me (*in litt.* January 22, 1943) that as far as he knew only one southern bluefin had been caught in the Eden area during the preceding season.

For the succeeding seasons, when the research vessel was absent on naval service, the following facts were gleaned from fishermen's reports:

1943 The 3+ age group reached Sydney, but showed retarded growth. There were no reports of the arrival of the 2+ age group anywhere on the coast.

1944 The 3+ age group reached the Sydney area, and also showed retarded growth. No reports were received of the 2+ age group.

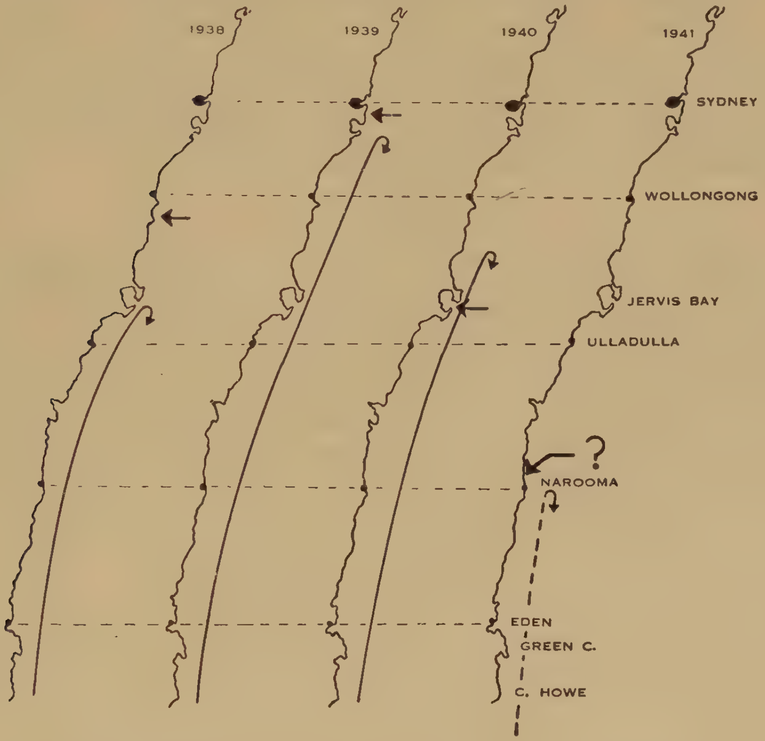

Fig. 10.—Penetration northwards along the New South Wales coast of the 3+ age group in various years; the arrow indicates the place of first appearance of the 2+ age group.

1945 The 3+ age group reached the Sydney area and the fish were up to size (i.e. over 17 lb). No reports of the 2+ age group were received.

1946-1948 No data.

1949 The 3+ age group reached the Sydney area. No reports of the 2+ age group were received.

1950 The 3+ age group was reported only as far north as Jervis Bay and there were no records of the 2+ age group (J. P. Robins).

1951 The 3+ age group reached about the same point as in 1950 and the only region where the 2+ age group was noticed to occur was in the Shoalhaven Bight (J. P. Robins).

(e) *Summary of Fluctuating Factors in Relation to Southern Bluefin Tuna*

In Table 12 the various fluctuating biotic factors which it is reasonable to associate with the southern bluefin tuna in New South Wales have been summarized. This was done in cooperation with Dr. Keith Sheard, who provided the data on the general plankton, euphausians, and salps to 1944-45, and Miss P. Kott, who continued them to 1949-50. For ease in comparison the data are represented by symbols. Thus for all of the variables the letter A represents good conditions or high numerical values in numbers of organisms and C adverse conditions and low numbers.

The data are not complete enough for clear correlations to stand out with respect to the plankton, but low plankton values, and particularly low euphausian numbers, tend to be associated with or to precede unfavourable features in the tuna. Thus there is an almost unbroken series of C symbols for the season 1942-43 and a complete series of A symbols in the season 1944-45.

XI. Feeding Habits

The southern bluefin tuna is an omnivorous and random feeder, and probably more than in any other local tuna its stomach contents reflect the relative components of the macroplankton and smaller nekton of the area in which it has been caught. Organisms ranging in size from small pelagic amphipods and euphausians to large fish such as 350 mm jack mackerel (*Trachurus novae-zelandiae* Rich.) figure in the diet. Various non-edible objects are often found in the stomach, small pieces of the sea-grass *Posidonia* being particularly frequent. Some of these have almost certainly been inadvertently swallowed whilst the tuna was being hauled in during trolling, but they may occasionally be taken in normal feeding. The tuna probably snap at them as they do at any likely food object. On one occasion a tuna was seen to dart at a piece of red paper from a cigarette packet thrown overboard from the F.R.V. *Warreen*. One fish had potato peelings in the stomach.

In eastern Australia the diet of the species is extraordinarily varied, and consists usually of small organisms, colloquially spoken of as "small feed" by fishermen, rather than larger food items. This may, however, vary from season to season. Thus in 1938 and in the spring of 1939 along the New South Wales coast, anchovies (*Engraulis australis* (White)) and pilchards (*Sardinops neopilchardus* (Steindachner)) were important components of the food items found in the stomachs. In 1940 and 1941 anchovies were less important and *Nyctiphanes australis* Sars and "small feed" were common in the stomachs.

From a series of weighings of the stomach contents of a representative sample of feeding southern bluefin tuna caught by trolling in New South Wales waters during October and November 1941 the following data have been compiled (individuals with empty stomachs being excluded):

Tuna Group	No. in Sample	Mean Weight of Stomach Contents	Heaviest Individual Stomach Contents
6–9 lb	12	26 g	55 g
15–18 lb	63	84 g	285 g

In any one stomach it is usual to find a heterogeneous assortment of food species—fish, crustaceans, and molluscs. Cephalopods are almost always associated

TABLE 12

FLUCTUATING BIOTIC FACTORS IN RELATION TO AVAILABILITY OF SOUTHERN BLUEFIN TUNA IN NEW SOUTH WALES

A, numbers large; growth rate good; penetration to northern waters. B, numbers moderate; growth rate retarded; penetration to central waters. C, numbers small; growth rate very retarded; penetration only to southern waters

	Plankton	Salps		Euphausiids				Southern Bluefin Tuna			Plankton
Summer Period	Prod'n. for Year	Months Present as Dominants	Nos.	Months Present as Dominants or Swarms	Nos.	Incidence of Breeding Swarms	Larval Nos.	Nos.	Summer Growth Rate (2+ age group)	Penetration Northward along N.S.W. Coast	Summer Intrusion of Slope and Ocean Elements
1938–39	A	Sept.-Oct.	B	Sept.-Jan.	A	A	A	B	A	B	B
1939–40	A	Oct.-Jan.	A	Sept.-Oct., Jan.	A	B	B	A+	B	A	A
1940–41	B	January	C	Aug.-?Sept.	B	B	B	A	A	B	B
1941–42	C	?	?	?	?	?	?	C	B	C	B
1942–43	C	?	?	? Jan.	C	C	C	C	B	C	C
1943–44	B	Aug.-Sept.	B	Sept.-Oct.	B	B	B	A	C	A	B
1944–45	A	Aug.-Nov., Jan. and Feb.	A	May-July, Sept.-Oct.	A	A	A	A	A	A	A
1945–46	C	July-Sept. March-May	A B	?	?	?	?	A	?	A	A
1946–47	B	October	C	November	C	?	?	?A	?	?	B
1947–48	B	July September	C C	?	?	?	?	?A	A	?	C
1948–49	A	November March	B C	July November	A A	?	?	?A	A	?	B
1949–50	A	March	B	?	?	?	?	A+	B	?	C
1950–51	A	?	?	?	?	?	?	C	?	?	C
1951–52	?	?	?	?	?	?	?	?C	?	?	?

with fish items and rarely are found alone. However, this may occur at times, as during the autumn of 1941 along the eastern Tasmanian coast, when the small squid, *Nototodarus gouldi* (McCoy), was predominant in the diet and many stomachs were crammed wholly with these organisms.

The largest fish habitually eaten are jack mackerel, mackerel (*Scomber australasicus* C. & V.), and pilchards. The largest jack mackerel recorded was a fish measuring 350 mm in total length found in a 35 lb bluefin caught off St. Helens, Tas., in June 1940. Jack mackerel between 200 and 300 mm in total length are commonly found in bluefin of the 20-30 lb size group, particularly in the Tasmanian region. Mackerel measure to 300 mm in total length, with fish 90-250 mm long reasonably common. Pilchards found in the stomachs range to 200 mm in total length. Anchovies measure from 50 to 150 mm in total length and the stomachs may be crammed with up to 50 or 60 of them. Other fish items include scad (*Trachurus declivis* (Jenyns)), to 230 mm; young barracouta (*Thyrsites atun* (Euphrasen)), to 200 mm; pearl fish (*Emmelichthys nitidus* Rich.), to 210 mm; young morwong (*Nemadactylus*), to 90 mm; pike (*Sphyraena novae-hollandiae* Günther), to 210 mm; young salmon (*Arripis trutta* (Bloch & Schneider)); young king barracouta (*Rexea solandri* (C. & V.)); blue sprats (*Stolephorus robustus* (Ogilby)); young marine eels; and myctophids.

Fish items in the "small feed" category comprise a wide variety of species, in their post-larval stages. The most frequently occurring are bellows fish (*Macroramphosus molleri* Whitley), bill fish (*Scombresox forsteri* C. & V.), trevally (*Caranx georgianus* C. & V.), and mackerel and clupeoid fry. There appears to be little difference in the size of food organisms eaten by the two smallest age groups (2+ and 3+) in the New South Wales region, as similar-sized prey items were found throughout the weight range of southern bluefin examined, namely, 6-20 lb. The mackerel fry ranged from 25 to 100 mm in total length, pilchard were 20-100 mm (a 78 lb tuna contained pilchards measuring 80-100 mm), anchovy 30 mm, leatherjackets 17-50 mm, bellows fish 10-40 mm (the largest seen was one measuring 65 mm), trevally 33-54 mm, scorpaenid post-larvae 12-50 mm, bill fish 75-90 mm, morwong 30-75 mm, barracouta 35-80 mm, king barracouta 56-66 mm, scad 25-50 mm, jack mackerel 60-72 mm, *Trachurus* (species unidentified) 15-80 mm, salmon 30-53 mm, *Gonorhynchus greyi* (Rich.) 80-90 mm., john dory (*Zeus australis* Rich.) 60-80 mm, leptocephalus stages of eels 60 mm, star gazer (*Gnathagnoides innotabilis* (Waite)) 40 mm, pearl fish 58-85 mm, box fish 7-10 mm (these were found in an 18 lb tuna), boar fish (*Zanclistius elevatus* (Ramsay & Ogilby)) 40-70 mm, rock cod (*Ruboralga*) 17 mm, hardyheads (*Atherina*) 37-45 mm, and *Upeneichthys lineatus* 30 mm. Some of the food items are unusual. Thus at Cape Pillar in south-eastern Tasmania in March 1941, 18-19 lb tuna were feeding on the fry (35-50 mm) of the Australian perch (*Percalates colonorum* (Günther)), usually found in rivers and estuaries. At the other extreme a 28 lb tuna caught about 6 miles east of Cape Peron in south-eastern Tasmania in October 1938 contained fry (38-48 mm) of *Lepidorhynchus denticulatus* Richardson, normally a deep-sea species occurring in about 350-450 fm.

Among the cephalopods the species most commonly eaten is *Nototodarus gouldi* (McCoy) and one 20 lb tuna in Tasmania contained 12 of them, of a mean body length of *c*. 230 mm. A 7 lb tuna (Port Kembla, N.S.W.) contained 50 individuals measuring 30-50 mm. Other cephalopods found in the stomach contents were *Enoploteuthis galaxias* Berry, *Calliteuthis miranda* Berry, *Argonauta nodosa* Solander, and *Octopus australis* Hoyle.

Crustacean food items consist principally of euphausians, of which the predominant species is *Nyctiphanes australis* Sars, which may serve as food for fish even as large as 30 lb. Though at times southern bluefin tuna may feed considerably on euphausians they do not do so as consistently as the striped tuna (*Katsuwonus pelamis* (L.)). Stomatopod larvae (those of *Squilla laevis* Hess have been identified) are an important item. Large pelagic amphipods (including *Phrosima semilunata* Risso and *Brachyschelus crusculum* Spence Bate) have been found in 17-22 lb tuna caught off Gabo Island and Cape Everard. Sometimes other invertebrates are found in the stomachs, including the swimming bells of the siphonphore *Diphyes*, salps, and chaetognaths.

In South Australia and in Western Australia the food items of the southern bluefin tuna are much less variable than in south-eastern Australia. In South Australia clupeoids, including pilchards, blue sprats, and anchovies, appear to be the main food. Sheard (1950, p. 73) has discussed seasonal variations in tuna feeding in these waters.

In Western Australia on the south coast, east of Cape Leeuwin, the pilchard is the overwhelmingly important food organism, and other prey species are comparatively insignificant. Mackerel may at times occur. On the west coast, north of Cape Leeuwin, the food items become more variable and leather-jackets, box fish, *Gonorhynchus greyi* (Rich.), *Sphyraena obtusata* C. & V., garfish, cephalopods, and *Squilla* larvae have been recognized in the stomachs.

There are no data on the feeding habits of the very large mature southern bluefin.

XII. Acknowledgments

I am indebted to Dr. K. Sheard, Division of Fisheries, C.S.I.R.O., for the identification of the Crustacea; to Miss Joyce Allan, Australian Museum, for the cephalopods; and for assistance with the fishes to Mr. G. P. Whitley, Australian Museum, and Dr. M. Blackburn (clupeoids), and Mr. J. A. Tubb, both of the Division of Fisheries. Examples of most of the prey items are preserved at the Australian Museum, Sydney.

For assistance in the statistical treatment and interpretation of the results I am indebted to Mr. N. Stenhouse, Division of Mathematical Statistics, C.S.I.R.O., whose office made the machine computations.

It remains for me to acknowledge my indebtedness for general assistance to my colleagues in the Division of Fisheries, and more especially to the following: Dr. H. Thompson, who always took a keen interest in the work; Mr. Stanley Fowler, whose confidence in the eventual establishment of a worthwhile tuna fishery motivated the investigations; Dr. Maurice Blackburn, a shipmate and fellow-worker from the outset, whose assistance and advice have been valuable right to the publication stage of the work; Mr. Graham Clark, a loyal gatherer of field data in the early *Warreen* days; and to Captains Alexander Flett, C. E. Pedersen, and Roy Downie, for their always willing help at sea. To outside cooperators I am particularly indebted to Mr. A. J. Fraser (Superintendent of Fisheries, Western Australia), C. E. Wellings (Eden, N.S.W.), and the late John Gregory (Western Australia).

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SOUTHERN BLUEFIN TUNA

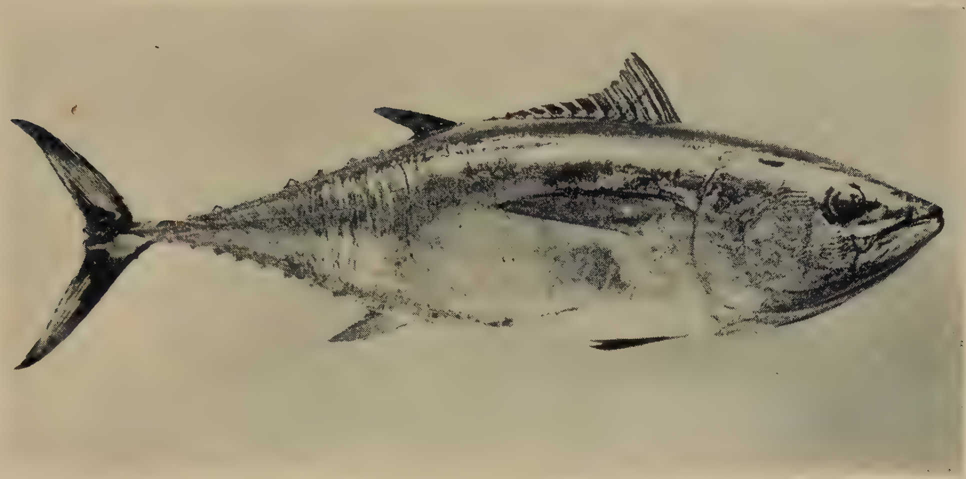


Fig. 1.—Southern bluefin tuna, 4+ age group.

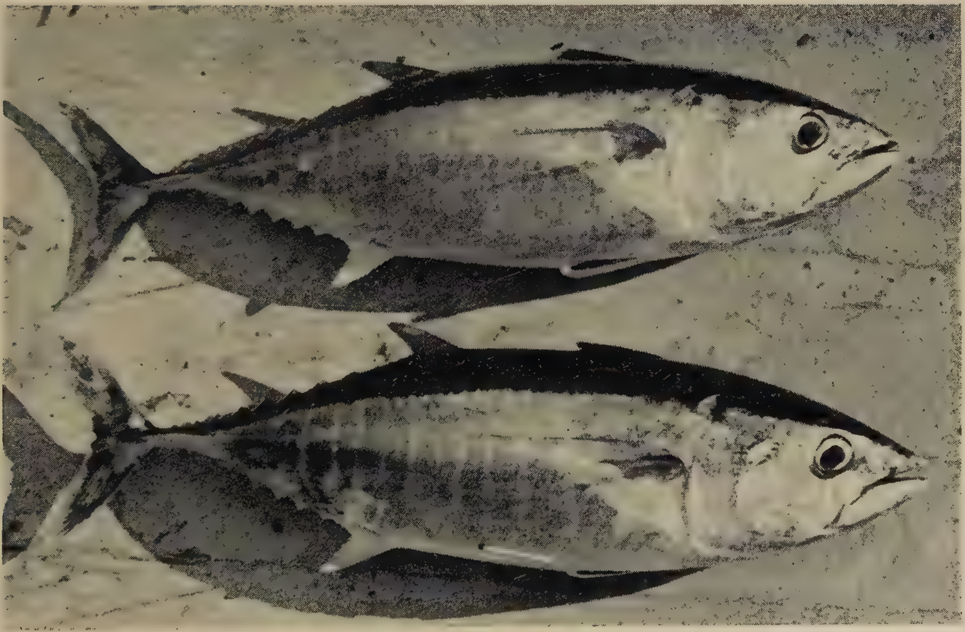
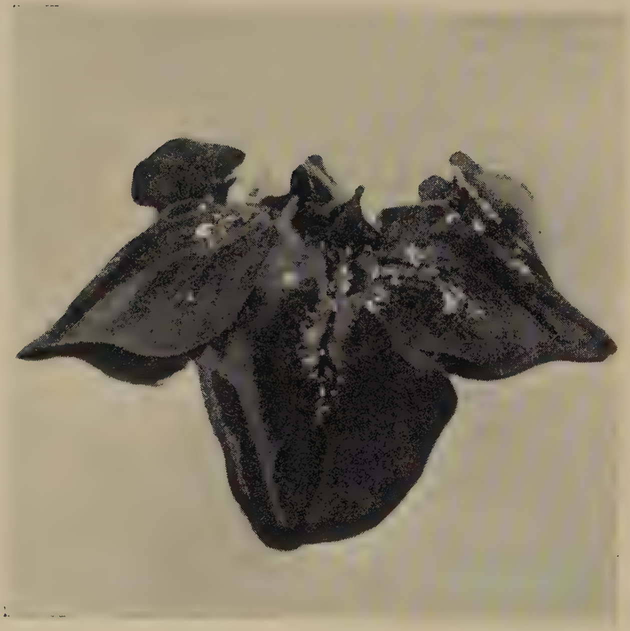


Fig. 2.—Southern bluefin tuna, length (to caudal fork) 56 cm; showing evanescent vertical bars.

SOUTHERN BLUEFIN TUNA



Liver of southern bluefin tuna, South Australia; weight 24 lb, length 82 cm.

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ADDITIONAL OBSERVATIONS ON THE BIOLOGY OF THE NORTHERN BLUEFIN TUNA, *KISHINOELLA TONGGOL* (BLEEKER), IN AUSTRALIA

By D. L. Serventy*

[*Manuscript received October* 13, 1955]

Summary

The northern bluefin tuna, *Kishinoella tonggol* (Bleeker), occurs along the whole of the north coast of Australia and on the east and west coasts as far south as Twofold Bay, N.S.W., and Cockburn Sound, W.A., respectively. Fin formulae, scale row and gill-raker data, and morphometrical characters are recorded separately for fish of the northern, eastern, and western regions. Marked regional differences occur; but it is considered that these can be largely (though not entirely) explained by differential growth of body parts, since only small sizes are found in the extreme north whereas large sizes predominate in the southern portions of the range. The hypothesis of two distinct species, suggested by size group distribution and regional variations, is rejected. Sexual maturity in *K. tonggol* is reached in the third year of life and spawning is in the summer. The species apparently feeds mainly on pelagic organisms.

I. Description

(*a*) *Introduction*

A detailed account of the Australian population of *Kishinoella tonggol* (Bleeker), 1852, has already been published, with significant references to the species under its various synonyms (Serventy 1942*b*, p. 101).

To these may be added the following:

Fowler (1904*a*, p. 761) referred a specimen 17½ in. in length (= 44·5 cm) from Padang, Sumatra, to *Germo germon* (= *Thunnus germo*); but from the taxonomic details (including the decisive gill-raker count) and the illustration (Fowler 1904*b*, Plate viii, lower figure) it is clearly a small specimen of *Kishinoella tonggol*.

Fowler (1936, p. 621) in an account of *Germo alalunga* (= *Thunnus germo*) gives a composite description of Italian and Sumatran material. Included is portion of the matter from the foregoing paper, including a gill-raker count of 5/16—a value absolutely diagnostic of *Kishinoella tonggol*—but the accompanying illustration is of an undoubted *Thunnus germo*.

Domantay (1940, p. 423), in an account of tuna fishing in southern Mindanao, provides an illustration (Plate 3, Figs. 1 and 2) of an "undetermined species of yellowfin" which appears to be *Kishinoella tonggol*.

To my earlier account the following meristic data, based on additional material, may be regarded as supplementary. The data are separated out under three geographical areas, as follows: Western Australia (Fremantle to the Lacépède Islands), northern Australia (Joseph Bonaparte Gulf to Torres Strait), and eastern Australia (Hervey Bay to Sydney).

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(*b*) *Fin Formulae*

The following are the frequencies of spines and rays in the various fins:

First dorsal fin

No. of spines	11	12	13	14
Individuals from:				
Western Australia	—	3	65	2
Northern Australia	1	2	76	4
Eastern Australia	1	2	33	2
Total:	2	7	174	8

Second dorsal fin and finlets

As has already been pointed out (Serventy 1942*b*, p. 103) this fin and the anal are thick and fleshy and the skin must be scraped off to expose the rays clearly enough for counting, a caustic solution being necessary to treat the fin in some cases. Thus only counts which have been made in this manner have been used in the present analysis.

The most anterior finlet, in both the dorsal and ventral series, is not infrequently adnate to the second dorsal and anal fins respectively, and as the posterior dorsal and anal rays resemble the finlets in form and size it is sometimes difficult to distinguish between them. In fact so often has an arbitrary choice to be made that it seems unprofitable to refer to them separately for taxonomic purposes, hence the totals of second dorsal fin rays and dorsal finlets are given.

Usually 14 second dorsal rays and nine dorsal finlets can be recognized.

The number of combined second dorsal rays and dorsal finlets is remarkably constant, being 23 from all areas. In Western Australia 10 individuals examined for this character gave 23 rays and finlets, as did three individuals from northern Australia. From eastern Australia 18 individuals were examined and 17 had 23 rays and finlets and one had 24.

Anal fin and finlets

The same considerations apply as for the preceding character. The number of combined anal rays and anal finlets counted in eight individuals from Western Australia was 22. From northern Australia two individuals had 22 and 23. From eastern Australia one individual had 21 and 14 had 22.

The usual arrangement is 14 anal rays followed by eight ventral finlets.

Pectoral fin

No. of rays	30	31	32	33	34	35
Individuals from:						
Western Australia	1	6	15	23	15	4
Northern Australia	—	—	—	2	—	—
Eastern Australia	—	2	7	13	7	2
Total:	1	8	22	38	22	6

The fin formula is, therefore, D. 11-14, 14-15, 8-9; A. 13-14, 8-9; P. 30-35. The most usual is D. 13, 14, 9; A. 14, 8; P. 33.

(c) *Scale Row*

Table 1 shows counts for samples in the three areas.

TABLE 1

SCALE ROW COUNTS

Area	Western Australia	Northern Australia	Eastern Australia
Number of fish	8	9	12
Mean length (cm)	79·2	42·5	94·0
Length range (cm)	63·5–95·1	37·0–48·9	81·5–111·8
Number of scales:			
Observed range	193–231	179–219	200–227
Mean number	219	197	219
Standard deviation	12·3	11·9	8·7
Coeff. of variation	5·6%	6·0%	4·0%

The scale row is difficult to enumerate with any accuracy and this probably accounts for some of the great variation in the counts. It is clear, nevertheless, that there is a slight average increase in the number of scales with the size of the fish (see Fig. 1, which is a scatter diagram of the combined data from all Australian localities).

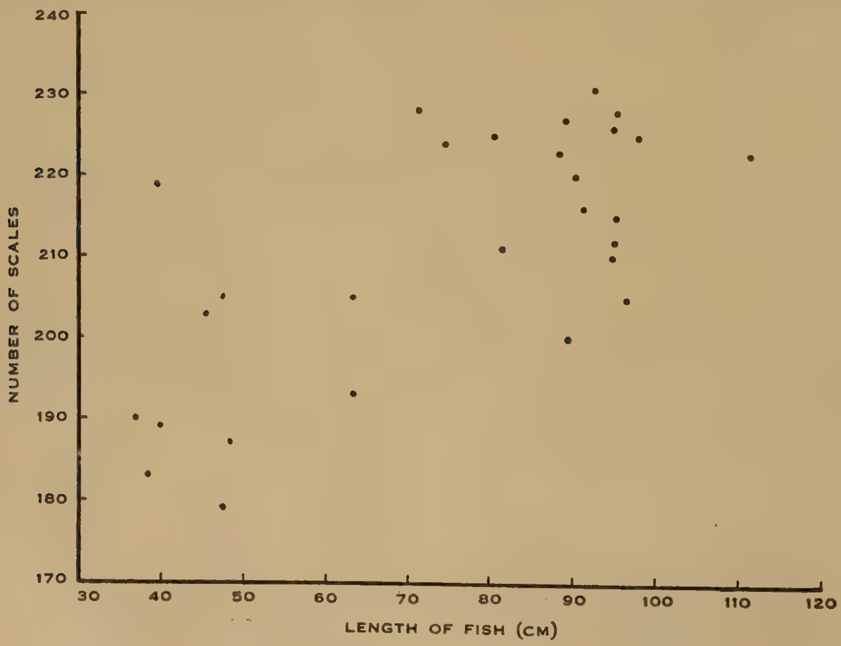

Fig. 1.—Scale row count. Scatter diagram of pooled samples.

(*d*) *Gill-rakers*

The gill-raker frequencies are as follows:

Dorsal limb

No. of rakers	5	6	7	8
Individuals from:				
Western Australia	5	37	25	4
Northern Australia	20	82	28	3
Eastern Australia	3	9	5	1
Total:	28	128	58	8

Ventral limb

No. of rakers	13	14	15	16	17	18
Individuals from:						
Western Australia	—	1	14	38	17	1
Northern Australia	1	3	40	76	11	2
Eastern Australia	—	1	8	8	1	—
Total:	1	5	62	122	29	3

Total rakers

No. of rakers	19	20	21	22	23	24	25
Individuals from:							
Western Australia	1	3	7	25	24	10	1
Northern Australia	2	12	30	56	25	8	—
Eastern Australia	—	3	6	4	4	—	1
Total:	3	18	43	85	53	18	2

The gill-raker formula is, therefore, 5-8/13-18 = 19-25. The modal formula is 6/16 = 22.

There are significant differences between the counts between the Western Australian and northern Australian samples, and there are insufficient data to compare the eastern Australian sample with them. The difference between western and northern material might merely reflect the difference in the average size of the fish, the northern specimens being the smaller.

(*e*) *Morphometrical Characters*

Standard measurements as recommended by the International Commission for the Exploration of the Mediterranean (1932; Russell 1934, as modified by Serventy (1942*b*, p. 104)), have been taken on material from eastern, northern, and Western Australia, the samples being from the same areas as delimited in Section I(*a*). With some specimens, particularly from northern Australia, a limited series of measurements was taken, as, for instance, only length, greatest depth, and length of pectoral fin. The original data are held by the Division of Fisheries, C.S.I.R.O., Cronulla, N.S.W.

Linear regression equations were fitted to the logarithms of the dependent and independent variables in each case, giving equations of the form

$$\log Y = \log A + b \log x ,$$

which in terms of the original units is a parabola with (usually) a non-integral index, thus

$$Y = Ax^b .$$

This relationship was chosen since, in common with much biological data, the larger measurements exhibit much greater variability than the smaller, resulting in heterogeneous errors of estimate in the different size groups. The variance becomes relatively more stable for all sizes when the logarithms are used.

The method of comparison of the samples from Western, northern, and eastern Australia amounts to the comparison of the linear regression coefficients in the various log-log relationships. If the three samples are drawn from the same population then the three coefficients should not differ significantly. If, as we have found for certain characters, the coefficients do differ significantly, then it is reasonable to suppose that the samples do not come from the same population. If the log-log relationships are linear then the interpretation of significant differences of the coefficient is relatively simple. If they are curvilinear, differences in the coefficients may merely reflect differences in range of fish sizes in the various samples. That is, caution must be exercised in interpreting significant differences in the coefficients if the ranges of size differ. The eastern and western samples cover similar ranges but the northern sample is composed of much smaller fish. Although these samples show no evidence of non-linearity (i.e. rectification was achieved with log-log transformation for all characters), comparisons involving the sample from northern Australia are made with the reservation that data from larger fish might possibly yield different results.

The results are set out in Table 2, where $\bar{x}$ = the mean of values of x; $\bar{y}$ = the mean of values of y; $s_{y \cdot x}$ = the standard deviation from regression (standard error of estimate); b = regression coefficient of y on x; and n = the number of specimens. The columns headed "Homogeneity of Regression Coefficients" give the significance (if any) of the various comparisons. The "Overall" column gives the significance pertaining to the comparison of the coefficients taken three at a time, and the next three columns are the comparisons of the pairs.

The results modify to some extent the suggestions regarding regional differences in body proportions made in the earlier study (Serventy 1942*b*, p. 105), wherein it was stated that, on the basis of the indices worked out between the various body measurements, Western Australian fish had relatively longer pectoral fins and more slender bodies than the eastern fish. It was suggested, however, that the differences might be due to differential (heterauxetic, allometric, heterogonic, or relative) growth during the life of the individual, as the samples compared were of different mean sizes. Differential growth occurs in a great many parts of the body. It can be readily detected from the value in Table 2 of b, which is the regression coefficient of log y (the part or organ concerned) on log x (the body length or other standard to which the organ is compared); Huxley (1932, p. 8) has called it the growth coefficient of the organ. When b is unity, or nearly unity, the organ increases proportionately

Table 2

REGRESSIONS OF BODY PROPORTIONS OF NORTHERN BLUEFIN TUNA FROM VARIOUS AREAS

L.C.F., length from snout tip to caudal fin fork

Independent Variable	Dependent Variable	Northern Australia					Eastern Australia					Western Australia					Homogeneity of Regression Coefficients (b's)			
x	y	$\bar{x}$	$\bar{y}$	$s_{y.x}$	b	n	$\bar{x}$	$\bar{y}$	$s_{y.x}$	b	n	$\bar{x}$	$\bar{y}$	$s_{y.x}$	b	n	Over-all	E.A. *v.* W.A.	E.A. *v.* N.A.	W.A. *v.* N.A.
Log L.C.F.	Log origin of 2nd dorsal fin	1.7086	1.4272	0.0064	0.9273	47	1.9436	1.6436	0.0060	0.9681	20	1.8926	1.6090	0.0205	0.8176	24	**	**	N.S.	**
Log L.C.F.	Log head length	1.7101	1.1488	0.0084	0.9324	51	1.9480	1.3639	0.0088	0.8471	24	1.9175	1.3349	0.0071	0.9352	15	N.S.			
Log L.C.F.	Log greatest depth	1.7113	1.0887	0.0158	0.9849	52	1.9486	1.3121	0.0149	1.1119	25	1.9020	1.2567	0.0166	0.8618	46	***	***	N.S.	**
Log L.C.F.	Log height of 1st dorsal fin	1.6416	0.6930	0.0201	1.0368	21	1.9414	0.9949	0.0213	0.9542	29	1.8891	0.9489	0.0158	0.9552	21	N.S.			
Log L.C.F.	Log length of anal fin	1.6416	0.6749	0.0225	1.3759	21	1.9428	1.0789	0.0289	1.2242	22	1.8942	1.0138	0.0271	1.2495	23	N.S.			
Log L.C.F.	Log pectoral fin length (along body)	1.7729	1.1148	0.0188	0.5206	31	1.9247	1.2135	0.0218	0.4699	13	1.9156	1.1972	0.0186	0.4227	31	N.S.			
Log L.C.F.	Log snout to origin of 1st dorsal fin	1.7047	1.1684	0.0086	0.8386	48	1.9422	1.3727	0.0084	0.9314	19	1.8932	1.3329	0.0107	0.9093	25	N.S.			
Log L.C.F.	Log snout to vent	1.7047	1.4645	0.0059	0.9438	48	1.9411	1.6842	0.0050	0.9444	19	1.8904	1.6352	0.0073	0.9274	23	N.S.			
Log L.C.F.	Log origin of ventral fin	1.7022	1.1965	0.0104	0.9035	43	1.9435	1.4075	0.0084	0.8046	20	1.8932	1.3627	0.0129	0.8632	25	N.S.			
Log L.C.F.	Log height of 2nd dorsal fin	1.6416	0.6877	0.0176	1.2353	21	1.9429	1.0683	0.0270	1.0886	22	1.8922	0.9994	0.0241	1.2126	22	N.S.			
Log body depth	Log inter-axillary diameter	0.9990	0.8476	0.0123	1.0425	21	1.2795	1.1312	0.0146	0.9743	15	1.2335	1.0802	0.0148	0.9301	24	*	N.S.	N.S.	*
Log head length	Log orbit	1.1467	0.3407	0.0251	0.4455	46	1.3628	0.4291	0.0346	0.7607	25	1.3283	0.4176	0.0301	0.5681	25	N.S.			
Log head length	Log maxillary	1.0847	0.6723	0.0153	0.9259	21	1.3494	0.9146	0.0061	1.0245	17	1.3107	0.8767	0.0080	0.9529	24	N.S.			
Log head length	Log pre-opercular	1.0614	0.9574	0.0103	0.9153	18	1.3503	1.2408	0.0074	1.0505	18	1.3107	1.2026	0.0061	0.9916	24	*	N.S.	*	*

* $P<0{\cdot}05$. ** $P<0{\cdot}01$. *** $P<0{\cdot}001$. N.S., not significant.

to the body length (the growth rate is constant). When b is less than unity the organ may be said to be growing at a slower rate than the body (in actual fact, the growth rate is continuously decreasing). Similarly when b is greater than unity the organ is growing at a greater rate than the body (that is, the growth rate is continuously increasing).

Differential growth in this species is perhaps most striking in the pectoral fin; the relative size of the fin during body growth is shown in Figure 2. The dots show the pectoral fin lengths of individual fish, expressed as percentages of the body length. The smaller, younger fish have relatively longer pectorals, which may extend beyond the vertical passing through the origin of the second dorsal fin (Plate 1).

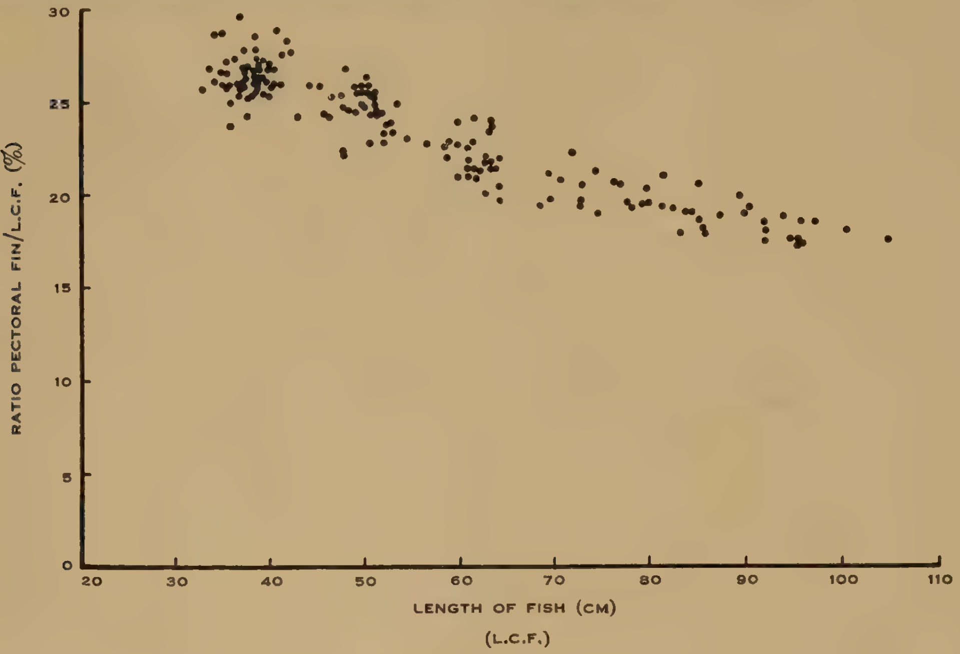

Fig. 2.—Length of pectoral fin (in extended position, along the body) in relation to body length.

The analysis adopted in the present paper substantiates the author's earlier suggestion (Serventy 1942*b*, p. 106) that the regional differences between the body length/pectoral fin ratios were due to differential growth. The analysis has shown that there is no significant difference in the pectoral fin relationships between samples from any of the three regions tested.

The analysis has confirmed that there is a real difference between the degrees of plumpness of the body (measured by the greatest body depth) in the samples from Western Australia and eastern Australia and also between those of the samples from Western Australia and northern Australia; the northern and eastern fish are alike in respect to this character. The analysis has also demonstrated a similar regional difference in the position of the second dorsal fin (the western fish differ from the eastern and northern fish, which are indistinguishable).

Two other characters show significant differences. In respect to the inter-axillary diameter there are differences between the western and northern fish only. The pre-opercular length in relation to the head length, whilst similar in eastern and western fish, shows significant differences as between the northern fish and those of both eastern and Western Australia.

These differences are referred to again in Section V.

II. Occurrence in Australia

(a) *General Remarks on Distribution and Abundance*

As has already been pointed out (Serventy 1941, p. 33; 1942*b*, 101) any real appreciation in the past of the relative abundance and extent of occurrence of this species in Australia has been prevented by its confusion with another species, the southern bluefin (*Thunnus thynnus maccoyii* (Castelnau), 1872). Almost all of the published references to *T. t. maccoyii* really apply to *Kishinoella tonygol* when they refer to tuna caught north of the latitude of Sydney.

The late Alan R. McCulloch never realized that under the name of *Thunnus maccoyii* he was confounding two species, though he had handled specimens of both. For many years specimens of *Kishinoella tonggol* were exhibited in the Australian Museum and the Queensland Museum, labelled as *Thunnus maccoyii.* Numerous photographs of anglers' catches illustrating the same species appear in the popular press, but the captions either directly or by implication refer to it as the southern bluefin (cf. Jewell 1935, p. 18; Anon. 1936; Pearce 1937, p. 4). The same is true of numerous items in the inspectors' reports of the New South Wales Fisheries Branch. These misidentifications, over a long period of time, not only obscured the true position regarding *K. tonggol* but gave an altogether exaggerated idea of the geographical distribution of *T. t. maccoyii.*

From the data now available *K. tonggol* is found to be perhaps the most abundant and important species of tuna in the Indo-Malayan and northern Australian region (see Fig. 3). It has been recorded northward to southern Japan, southward to southern Australia, westward to the Maldive Islands, and eastward to Papua and New Britain. In Australia it is found throughout the year along the coast within the tropics, and pays seasonal visits south along both the east and west coasts. In southern Queensland it is considered to be a winter visitor, while along the New South Wales coast it has been recorded as far south as Twofold Bay in the late summer and autumn (from about December to May). It may perhaps extend south as far as Gabo Island, but it can be said with fair assurance that it is not found in Victorian or Tasmanian waters. In Western Australia it ranges at least as far south as Cockburn Sound, in the Fremantle area, where individuals may be caught throughout the year, and no clear seasonal movement is apparent as yet. The species may possibly occur as far as Geographe Bay, but it certainly is not found on the south coast of Western Australia east of Cape Leeuwin.

Much of our information is derived from the observations and trolled catches of the C.S.I.R.O. Fisheries Research Vessels *Warreen* and *Stanley Fowler*, and both worked usually inside the 100 fm line. How far beyond this limit the tuna shoals extended is not known.

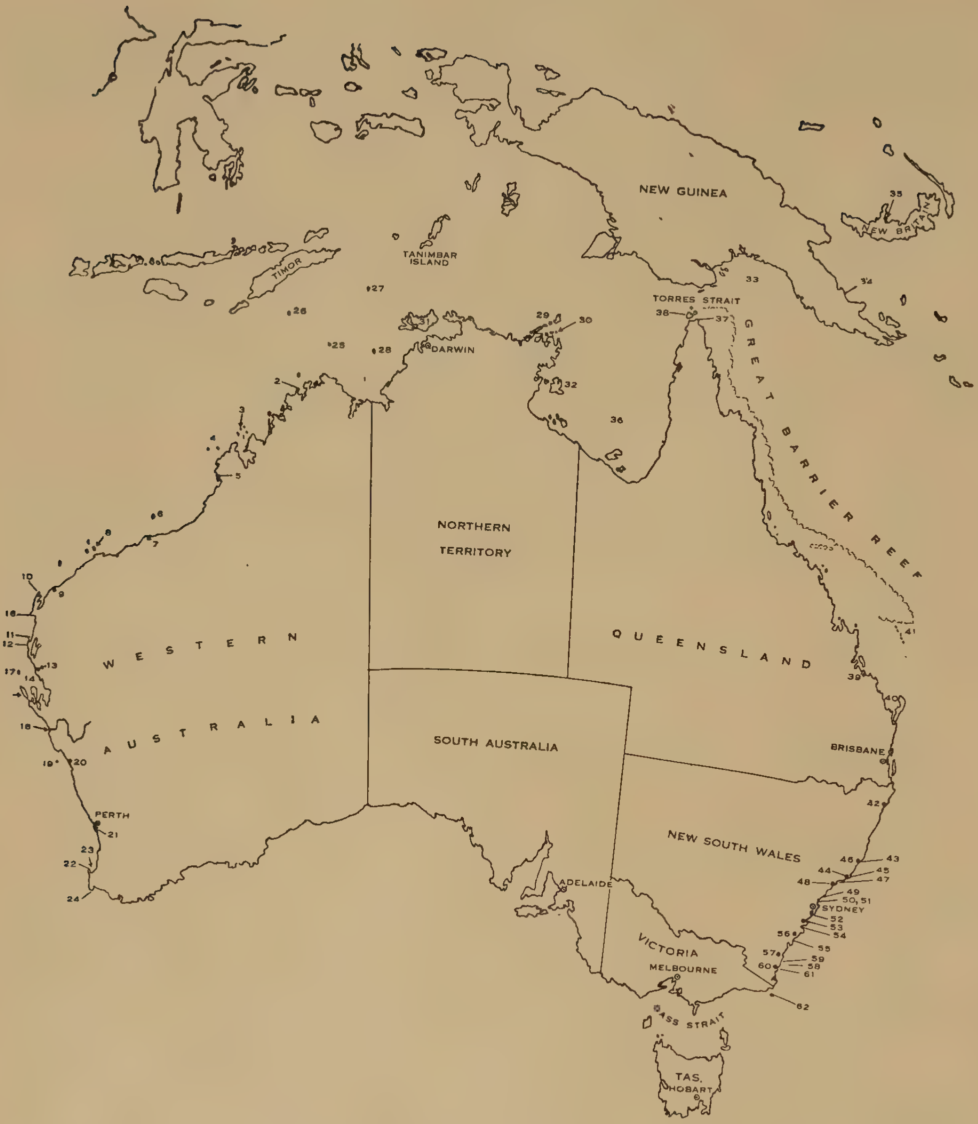
NEW GUINEA
NEW BRITAIN
TANIMBAR ISLAND
TIMOR
TORRES STRAIT
DARWIN
GREAT BARRIER REEF
NORTHERN TERRITORY
WESTERN AUSTRALIA
QUEENSLAND
SOUTH AUSTRALIA
BRISBANE
NEW SOUTH WALES
PERTH
ADELAIDE
SYDNEY
VICTORIA
MELBOURNE
BASS STRAIT
TAS.
HOBART

Fig. 3.—Map of Australia-New Guinea area, showing localities referred to in the text.

Western Australia

1. Joseph Bonaparte Gulf
2. C. Voltaire
3. Buccaneer Archipelago
4. Lacépède Is.
5. Broome
6. Bedout I.
7. Port Hedland
8. Legendre I.
9. Onslow
10. North West Cape
11. C. Farquhar
12. Red Bluff
13. Carnarvon
14. Shark Bay
15. Dirk Hartog I.
16. Point Cloates
17. Dorre I.
18. Murchison River
19. Abrolhos I.
20. Geraldton
21. Fremantle
22. C. Naturaliste
23. Geographe Bay
24. C. Leeuwin.

[*For continuation see opposite page.*]

From the east of Australia there are fishermen's reports of "bluefin tuna" averaging 12 lb in weight in the region of Swain Reefs, Qld., and these are possibly attributable to this species. There are, however, no records further east in the Pacific. In the New Guinea area the species has been very infrequently caught by fisheries investigators. Fish measuring 71-77 cm in length were taken in the Gulf of Papua in March 1943 by the late Capt. A. Flett (formerly of the F.R.V. *Warreen*). The M.V. *Fairwind* took no specimens at all of this species during fisheries surveys around the shores of south-east New Guinea and New Britain. However, J. A. Tubb examined a 53 cm specimen taken at Cape Sudest (on the north-east of Papua) in May 1943. In July 1945 Lieut. G. White of A.N.G.A.U. caught an undoubted specimen of this species, weighing about 18 lb, at Talasea on the north coast of New Britain.

On the west coast of Australia knowledge of the occurrence of the pelagic fishes was advanced by aerial surveys between 1942 and 1946, by the cruise of the ketch *Isobel* chartered by the C.S.I.R.O. in 1945, and by the operations of the F.R.V. *Warreen* between 1947 and 1949. The aerial surveys (Fowler 1944, p. 31), which were conducted within 50 miles of the coastline, disclosed that nearly all the tuna observed were found, broadly speaking, between North West Cape and the Lacépède Islands, with the greatest concentrations between Port Hedland and Broome. The shoals seen from the air appeared to be comparable in magnitude with anything seen of other tuna species in other parts of Australia. The peak of the occurrence was in the winter months. Two species of tuna predominate in this region, *K. tonggol* and *Euthynnus alletteratus* Rafinesque, and it is presumed that a not inconsiderable part of the shoals seen were of the former species.

During the *Isobel* survey in August-December 1945 this species was taken from off the mouth of the Murchison River north to the Lacépède Islands, with most catches north of Shark Bay to Broome. Of the 31 specimens trolled by the

Fig. 3 (*Continued*).—Map of Australia-New Guinea area, showing localities referred to in the text.

Northern Australia

25. Van Cloon Shoal
26. Sahul Bank
27. Troubadour Shoal
28. Flat Top Bank
29. Wessel I.
30. English Company's Is.
31. Melville I.
32. Groote Eylandt.

New Guinea Area

33. Gulf of Papua
34. C. Sudest
35. Talasea (New Britain).

Queensland

36. Gulf of Carpentaria
37. C. York
38. Booby I.
39. Gladstone
40. Hervey Bay
41. Swain Reef.

New South Wales

42. Ballina
43. Hastings River
44. Forster
45. Wallis Lake
46. Port Macquarie
47. Port Stephens
48. Newcastle
49. Terrigal
50. Broken Bay
51. Hawkesbury River
52. Cronulla
53. Wollongong
54. Shellharbour
55. Jervis Bay
56. Nowra
57. Narooma
58. Merimbula
59. Bermagui
60. Eden
61. Twofold Bay
62. Gabo I.

Isobel the majority were the typical large fish occurring on the west coast, the heaviest weighing 34 lb and measuring 105 cm.

The *Warreen* operated for three seasons, 1947, 1948, and 1949, during the late winter months along the north-west coast of Western Australia, but in the former two years only as far north as Onslow. Catches of *K. tonggol* during these cruises were inconsiderable (for discussion of the problems of capture see Serventy 1942*a*, p. 94) but presumed shoals were fairly plentiful. Altogether only 38 specimens were trolled.

Concerning the possible occurrence of this tuna in strength in the pelagic region far off the Western Australian coast, some reference must be made to the observations of Capt. (later Admiral) Phillip Parker King during hydrographic surveys in this region in H.M.S. *Bathurst* in the early part of the last century (King 1827, p. 218). King identified the tuna caught as "*Scomber thynnus*", and as previously pointed out, that species (i.e. *Thunnus thynnus* in modern terminology) is the most readily confused of all tunas with *K. tonggol.* The full reference, dealing with the period March 3-11, 1822, is as follows:

"On the 3rd at noon we were in latitude 18° 45′ 18″, and longitude 111° 4′ 15″, when a breeze sprang up from the S.E., and carried us within the influence of the trade, which blew steadily between S.S.E. and S. b. E. and advanced us on our passage, but carried us considerably to the westward. On this course we were accompanied by immense shoals of albicores (*scomber thynnus*, Linn.), but they were of small size; very few measured more than twenty inches in length, and the average weight about ten pounds . . . Tropic and other oceanic birds, some of a dark brown colour, hovered about us, and were our daily companions, particularly the latter, which preyed upon the small fish that were pursued by the albicores."

On March 14, the *Bathurst* was in lat. 27° 49′ S., long. 101° 1′ E. In this general region, out from North West Cape and Shark Bay, it is of interest to record that petrels nesting on the Western Australian islands are met with in numbers, on the steamer track to Colombo, as far as about longitude 107° E., but not beyond.

(*b*) *Movements in New South Wales*

A summary of the records available from New South Wales gives suggestive evidence of seasonal migration and of the commercial potentialities of the beach net fishery to which reference has already been made (Serventy 1942*a*, p. 94; 1942*b*, p. 101).

The following items are from the annual reports of the New South Wales State fisheries authority (and as stated earlier are attributed directly or by inference erroneously to *T. maccoyii*). For the items from 1897 to 1927 the references are to the departmental annual reports for the year mentioned, the year of publication being given in brackets.

1897 (1898, p. 13)

On March 17 "a school of albicore found their way into the harbour (Wallis Lake), some of which were speared by the half-castes; but the fish being little known no use was made of them".

1903 (1904, p. 39)

Schools of tuna entered the Hastings River from the sea in February.

1904 (1905, p. 56)

"There was a large school of bonito off Middle Head on the 11th and 12th of April."

1905 (1906, p. 52)

"Bonito" were reported as passing and entering the Hastings River in December.

1913 (1914, pp. 108, 109)

In February at Port Stephens many large tunny were taken by visiting anglers, and in the same months, at Pambula at South Head, Twofold Bay, "large shoals of tunny were observed by a fisherman. These great mackerel were chasing a shoal of common mackerel, they came quite close to the launch".

1915 (1916, p. 5)

"In January large bodies of Southern Tunny (*sic*) made their appearance in the waters of Port Stephens . . . In March a curious condition prevailed in the Rose Bay Baths on the occasion of a Swimming Club competition, when the races had to be postponed owing to the baths being choked with thousands of small pilchards. Schools of Tunny were in evidence in the vicinity, and the small fish evidently crowded into the baths as a place of refuge . . ."

(p. 33) "During March a catch of 70 tunny was made with the net at Rose Bay. In March and April shoals of tunny were observed in the harbour, following large shoals of pilchards" (the fish realized 12/- and 36/- per dozen at the Sydney Fish Market).

1917 (1918, p. 4)

Tunny were in evidence at Port Stephens in March and "several big-game fish-hunters visit Port Stephens annually to participate in the sport of catching Spanish Mackerel, Tunny and Kingfish, and the local fishermen with launches reap a harvest while the big-game fish are in the Port. One man with a small launch earned as much as £14 a week in taking out parties to troll for these fish". Tuna were also in abundance in the waters of Port Hacking, near the heads, during March.

1918 (1919, p. 34)

Sydney Fish Market prices for tuna during March are given as 30/– and 36/– per dozen.

1919 (1920, p. 18)

At Port Stephens "both tunny and Spanish Mackerel were plentiful from the middle of February to May, and fine sport was obtained. They arrive here apparently from the south, and pass northward. They carry no ova. They follow sea garfish, and their migration along the coast seems more a matter of food than for breeding purposes. They are very powerful and swift and weigh up to 35 lb. and over . . ."

(p. 21) Small schools of tunny were observed in the bay at Hawkesbury River "during the early part of the year" following shoals of small fry.

Prices at the Sydney Fish Market during March—the only time of the year incidentally at which tuna appeared to be marketed—were given as 18/- a dozen.

1920 (1921, p. 20)

Tunny were numerous at Lower Port Stephens from March until the end of May.

1927 (1928)

Prices during March at Sydney Markets were 3d. to 4d. per pound.

The following data have been accumulated since the Division of Fisheries, C.S.I.R.O., has been making enquiries into the subject.

1935

A. F. D'Ombrain, of West Maitland, and a big-game angler operating in the Port Stephens area, caught *K. tonggol* weighing between 25 and 35 lb; the catch was illustrated in the *Newcastle Morning Herald* of March 29.

1936

A. F. D'Ombrain reported that he caught a 45 lb tuna (the largest of the species he had ever taken) off Tomaree Head, Port Stephens, on May 3.

1937

In January, 45 large tuna, 35-45 lb in weight, were netted on False Bay Beach, Port Stephens.

1940

In February numbers of tuna were seen off Wollongong. In March several small scattered schools were present off Merimbula.

1941

The occurrences of *K. tonggol* along the New South Wales coast during this year and the commercial catches made have already been published (Serventy 1942*a*, p. 95). Between mid March and early May over 6000 lb of tuna were caught by beach seines at Port Hacking, Jervis Bay, Bateman's Bay, and Merimbula, and shoals were also reported at Middle Harbour, Port Jackson, Hawkesbury River, off Newcastle, and at Ballina. From reports this appeared to be an unusually good year for the species. W. L. Packenham, fisheries inspector at Merimbula, stated that this appeared to be the third time these fish had been captured in local waters. In April 1930 very extensive schools were in Merimbula Bay for about 3 weeks and in April 1935 small schools travelled the beaches of Eden and Merimbula for about 1 week. However, in his weekly report of pelagic fishes, dated March 9, 1940, Mr. Packenham stated that "ocean fishermen report having passed through several small patches of tuna; the fish are fairly scattered and will not take jigs". From the time of the year and their behaviour these would evidently be *Kishinoella*.

1942

In March a school estimated at 1000 tons was in Twofold Bay and fishermen caught 4 tons with a salmon seine.

In April a school of 300 worked its way in the upper waters at Port Stephens, between Pelican and Carcair Points, feeding on sea garfish. Schools were also reported at Port Hacking and Merimbula.

On May 5 a catch of 2½ tons was netted out of a large school at Twofold Bay, after it had been broken up by porpoises. A school of about 100 was observed at Port Hacking and tuna were also reported at Port Stephens.

1943

In February, 200 tuna were reported in the Wagonga River, Narooma, feeding on garfish and anchovies, and on February 21 the first tuna of the season was reported by fishermen at Bate Bay, Cronulla.

In early March, 16 fish were caught at Bate Bay and 150 at Twofold Bay. At the end of March and early April many schools were reported on the south coast, and the Narooma cannery received 482 fish (10,609 lb) from Bermagui, and 145 fish (7714 lb) from Merimbula, all netted by beach seines. In mid April some fish were still present at Twofold Bay.

1944

In February and March several large schools of tuna were reported near Terrigal and 5600 lb were netted. In March, 98 were caught at Cronulla and 42 at Bermagui. A very large school was observed at Narooma on March 13. In December tuna were observed near Terrigal.

1945

On February 24, tuna were reported at Port Hacking and figured in the local inspector's reports until April 28. Large schools were reported during March and, on April 7, were seen between Lilli Pilli and Gymea Bay. Big schools entered Botany Bay on March 6, and entered Quibray Bay along Kurnell beach and Yona Bay along La Perouse beach; some were caught and sold as bait to the leatherjacket fishermen as there was no other local demand for them. A school of 200 was at Kurnell on April 7. During March large schools were reported in Port Stephens and small schools at Woy Woy and the mouth of the Hawkesbury River.

On the south coast some of the reports are indefinite as to identification, but the species was positively identified on February 25 by the fisheries inspector at Twofold Bay (160 fish caught, averaging 25 lb) and Pambula Bay (300 caught). In late March, four fish were netted at the Wagonga River and identified (weight 22 lb). Reports from Bateman's Bay of March 6 (tuna feeding on pilchards) and Shellharbour were probably of this species.

1946

No reports of occurrences are to hand from the Port Hacking area but at Broken Bay and Pittwater large schools were reported by the fisheries inspector on February 25 and fish were observed until March 18. A. F. D'Ombrain reported that at Port Stephens and off Newcastle tuna were caught during April but did not appear to be as numerous as in other years "as the usual movements of pelagic fish have been greatly upset by the recent rains (1,000 points fell in one day, on April 18)".

No reports came from the far south coast but there were reports of tuna at the entrance to Jervis Bay and off Beecroft Head on February 16 and off Lake Illawarra South on March 23 and April 8 and 29. They were observed in the Narooma area in May. On March 31, 2 tons of large tuna (heaviest 35 lb) were received at the Narooma cannery from the Sydney Markets (origin unknown, species not recorded but probably this species).

1947

At Port Hacking tuna were reported from February 22 onward. On February 8, two large schools at Lilli Pilli were estimated to cover 1 acre. Samples at Sydney Fish Markets were examined from Currarong (near Nowra) on March 31 (23 fish) and from Broken Bay on June 12 (48 fish).

1948

A sample of 56 fish from Cronulla was examined at the Sydney Fish Market on March 3.

1949

Samples from Palm Beach were examined at the Sydney Fish Market in February (73 fish).

Study of these records suggests that the direction of movement along the coast is northward during this late summer and autumn period.

III. Distribution of the Size Groups

There are striking differences in the geographical distribution of the size groups of this species and a clear explanation of them is not yet apparent. Kishinouye (1923, p. 449) stated that in southern Japanese waters—at the northern limits of occurrence of the species—the usual length was about 70 cm, and the usual weight about 6 kg (= 13 lb) with a maximum of 12 kg (= 26 lb). He considered it to be the "smallest tunny not only in our waters, but perhaps in the world". Delsman and Hardenberg (1934, p. 336) likewise consider it a small species (termed by them the "dwarf tunny"), the length reaching to only 50-75 cm. Warfel (1950, p. 11) stated that the average weight of 40 specimens trolled in the Philippines was less than 5 lb, the largest weighing 11·5 lb.

In Australia every gradation in weight has been found, from just over 1 lb to a maximum of about 60 lb. The larger size groups, however, predominate in the southern part of the area and only large fish, averaging 20-25 lb in weight, have been caught so far in the extreme south. On the other hand, in the Timor Sea region in the extreme north, so far only the smaller size groups, up to a maximum of 10-12 lb in weight, have been taken. The distribution may be described in greater detail.

In northern Australia, from the special tuna cruises conducted in 1949 with the *Warreen* and the *Stanley Fowler*, it was found almost exclusively that in the region from the Gulf of Carpentaria in the east to the Kimberley Division of Western Australia in the west, and over most of the Timor Sea and Sahul Shelf, only small individuals of up to 12 lb weight were encountered. The largest specimen caught in this region was one weighing 13 lb (74·7 cm in length) in the Joseph Bonaparte Gulf on September 26. The fish which were caught on these cruises fell into three fairly well marked size groups, those taken between September 1 and October 20 being shown (in 2-cm class intervals) in Figure 4. On the assumption that these represent successive age groups the position of the modes on a growth curve would suggest that they are, respectively, 2-year-old fish (1+ year group), of a modal length (measured from the snout to the caudal fork) at this period of 38 cm and a mean weight of 2·2 lb; 3-year-old fish (2+ year group), with a modal length of 51 cm and a mean weight of 5·0 lb; and 4-year-old fish (3+ year group), with a modal length of 62 cm and a mean weight of 8·25 lb.

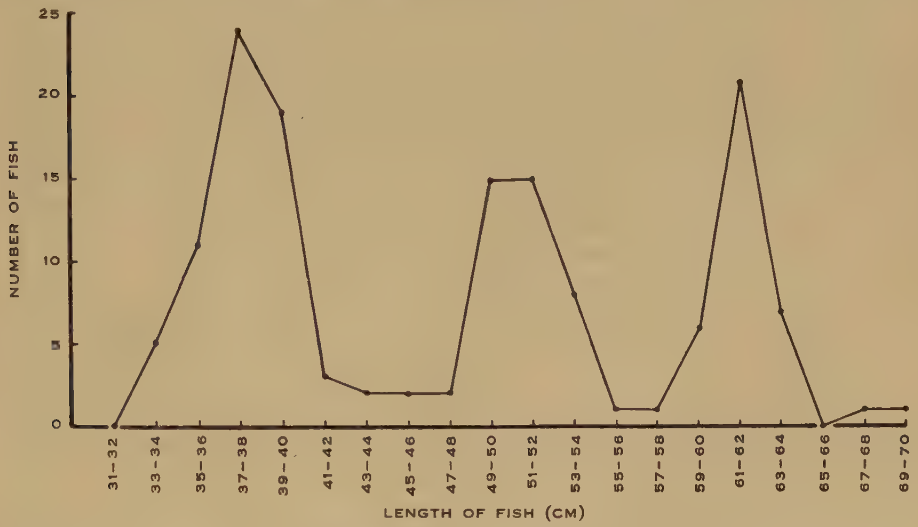

Fig. 4.—Length frequencies of *Kishinoella tonggol* taken in northern Australia, September-October 1949.

The fish of the smallest group, measuring 33-41 cm and weighing 1 lb 4 oz to 3 lb 7 oz (the presumptive 1+ age group) were found during the 1949 survey only in the region of the Joseph Bonaparte Gulf, between the Kimberley Division of Western Australia and the Northern Territory. The *Stanley Fowler* trolled many specimens during September and October in the Gulf itself and Van Cloon Shoal, over Sahul Bank, towards Troubadour Shoal, and over Flat Top Bank. Fisheries Inspector J. E. Bramley of the Western Australian Fisheries Department trolled two specimens of this size group off Cape Voltaire, in the Joseph Bonaparte Gulf area, in January 1945, when he was on war service with the Royal Australian Navy. No fish of this size group have been recorded in the eastern part of the Timor Sea or in the Gulf of Carpentaria. However, on September 25, 1948, the *Warreen* trolled four examples of this group off Dirk Hartog Island on the mid Western Australian coast; they measured 34-39 cm in length.

Fish of the second size group, measuring 46-54 cm and weighing 3 lb 11 oz to 6 lb 4 oz in September-October (the presumptive 2+ age group), were taken by the *Stanley Fowler* in 1949 in two rather widely separated areas: (i) intermingled with the former group in the Joseph Bonaparte Gulf region, and (ii) at the north-western end of the Gulf of Carpentaria, out from the Wessel and English Company's Islands. In September 1943 Fisheries Inspector X. W. Stathy, of the Western

Australian Fisheries Department, trolled a fish of this group off Melville Island when on war service with the Royal Australian Air Force in the Darwin area. The *Warreen* also took this group north of Dorre Island (northern approaches to Shark Bay) on September 26, 1947, and another off Cape Farquhar on October 4, the fish measuring 51-58 cm. Fish probably of this group were also taken off Point Cloates on November 2, 1949.

The third group, measuring 58-68 cm and weighing 7 lb 3 oz to 11 lb 8 oz (the presumptive 3+ age group), was trolled by the *Stanley Fowler* throughout the northern area, from the Gulf of Carpentaria to the Sahul Bank. It was the only size group of the species taken in the Darwin fish traps by Inspector Stathy during the winter months of 1943. It is also the only size group trolled by Capt. F. E. Wells, of the Northern Territory Administration, during his patrols of the coastline between Darwin in the west and Groote Island in the east; Capt. Wells is emphatic that he has never met with either of the two smaller size groups in this eastern sector. This group had also been taken on the mid Western Australian coast in earlier surveys. On August 16, 1943, a fisherman caught a 64 cm specimen between Geraldton and the Abrolhos Islands. The *Isobel* trolled a 62 cm fish off Legendre Island on September 25, 1945, and another, 61 cm long, off Bedout Island on September 28. The *Warreen* caught a 69 cm fish off Cape Farquhar on October 4, 1947, and two, 66 and 67 cm, off Cape Inscription on November 2. In the following year, on September 14, 1948, she caught three fish, 67-68 cm, between Cape Inscription and Carnarvon. On September 8, 1949, a 64 cm specimen was trolled off the Lacépède Islands and on September 13 a 69 cm fish off the Buccaneer Archipelago. The fish referred to by King (1827) would probably fall into this group.

On the eastern Australian coast I trolled a specimen approximating to this size group in Hervey Bay, Qld., in March 1943, the fish measuring 70 cm. There are no records of specimens as small as this, or smaller, being taken further south.

There is insufficient material to analyse definitely the composition of the larger sizes of tuna caught. However, in the southern parts of the range the majority of fish caught in the autumn months in the New South Wales region appear to form a homogeneous size group with a mean length of about 94 cm and a mean weight of 26 lb. This approximates to the mean size taken in similar latitudes in Western Australia. Fish of the intermediate sizes are taken further north along both the east and west coasts. The points furthest north where these big fish (i.e. of the 26 lb group and larger) have been taken are Torres Strait in the east (a 23 lb fish measuring 94 cm in length was taken by the *Stanley Fowler* in the western approaches to Torres Strait, near Booby Island, on July 16, 1949), and the Lacépède Islands in the west (a 92 cm fish was taken by the *Isobel* on October 18, 1945). As stated previously no fish approaching these sizes has been taken in the intervening section in northern Australia, the largest known from this region being a 13 lb fish (45 cm long) from Joseph Bonaparte Gulf.

As previously stated the southern limits where large individuals of the species have been recorded in Australia are Twofold Bay, N.S.W., in the east, and Cockburn Sound, Fremantle district, in Western Australia.

IV. AGE AT FIRST MATURITY AND SPAWNING HABITS

From observations on the *Stanley Fowler* cruise in the late winter of 1949, it was found that the size group with a mode of 38 cm (the presumptive 1+ age group) were immature fish with undeveloped gonads. The group with a modal length of 51 cm (the presumptive 2+ age group), and all larger fish, had enlarged, developing gonads. Thus this species begins to be sexually mature towards the end of its third year of life, on our tentative system of age determination.

Spawning apparently takes place in the summer months and definitive ova and fish with milt flowing have been observed in late September and October.

Fish with spent gonads have been examined in New South Wales in the autumn (early April). It is likely that most of the fish travelling along the New South Wales coast at that season are fish which have recently spawned.

V. THE QUESTION OF LOCAL RACES

The interesting distribution of the size groups, as outlined in Section III, poses a number of questions which at the moment cannot be satisfactorily answered, and their discussion is largely speculative. The localization of the larger sizes to the waters of the east and west coasts of the continent would suggest that there are two major breeding stocks, but as both the presumptive 2+ and 3+ year groups are sexually mature fish and the latter at least have a continuous distribution along northern Australia, sexually mature individuals may be said to occur throughout the range of the species in Australia. Further, more data are required before it can be definitely claimed that large fish are really absent from the Indo-Malayan area.

The peculiar distribution of the size groups suggested to the author at one time that two species existed. The smaller fish, of the 1+, 2+, and 3+ year groups, differ strikingly in appearance from the larger individuals (cf. Plate 1, Figs. 1 and 2); and before the author had intermediate sizes for comparison he had tentatively ascribed these smaller fish to a new species of *Kishinoella*, but fortunately the description never passed beyond the manuscript stage. The smaller fish have the head longer in relation to body length; the body deeper; the first and second dorsal fins, the ventral fins, and the vent placed more posteriorly in the body; the maxillary longer in relation to the head; and, most striking of all in general view, the eye much larger and the pectoral fin much longer than in the bigger fish. Some of these differences can be perceived in the large and small specimens of Bleeker's type material of the species (see Serventy 1942*b*, Plate 3).

The extensive series taken by the *Stanley Fowler* in conjunction with the material accumulated since 1942 has enabled us to explain most of these differences as really due to differential growth. In respect to two of the most striking differences between the very small and the very large fish, namely, the size of the eye and the length of the pectoral fin, there are no significant differences between samples from the western, northern and eastern areas.

However, some of the other body proportions, on detailed statistical analysis, *do* indicate regional differences (Section I(*e*)). These concern the relative position of the second dorsal fin, the comparative slenderness of the body (measured by the greatest depth and by the interaxillary diameter), and the size of the preopercular in relation to head length. The differences are detailed above, and in respect to them Western Australian fish differ on all four characters from northern Australian fish, and on two of them from eastern Australian fish. Eastern Australian fish differ in one of the characters from northern Australian fish.

No differences can be detected in other characters, except in the gill-raker counts, where there are differences between the Western and northern Australian samples (Section I(*d*)).

The morphometrical and gill-raker differences just indicated do not necessarily mean that there is breeding discontinuity between the fish of the three areas sampled. They do reveal, however, that some morphological differences have developed between them. Whether these are part of a continuous gradation (a cline series) or indicate discrete breaks in the breeding distribution, is impossible to determine on the evidence at hand.

VI. Feeding Habits

Specimens caught by trolling usually either had empty stomachs, or the food remains were far digested. Most of the specimens examined which contained freshly captured food in the stomachs were net-caught fish.

A wide variety of food organisms were recorded during the investigations, but pelagic forms predominated.

Details of the stomach contents of a net-caught sample of *Kishinoella* from Port Hacking, N.S.W., have been given (Serventy 1942*a*, p. 99). In this case the food eaten by this particular school consisted almost exclusively of pilchards (*Sardinops neopilchardus* (Steindachner)), with insignificant numbers of mackerel (*Scomber australasicus* Cuv. & Val.) and scad (*Trachurus declivis* (Jenyns)).

In Western Australia no particular food preferences are indicated by the data available. In northern waters *Harengula*, pilchards (northwards to Red Bluff), and anchovy predominate among the fishes; leatherjackets, garfish, northern mackerel (*Rastrelliger kanagurta* (Cuvier)), mullet (*Mugil compressa* Günther), flying fish, *Gerres ovatus* Günther, and various plectognaths also occur. Crustacea, particularly stomatopod larvae and prawns, are commonly eaten. Cephalopods are also frequently found in the stomachs and there is no evidence that they are taken only when fish are absent.

In northern Australia flying fish, anchovies, and other small clupeoids are the preferred diet among fish species, with leatherjackets common. Crustacea figure prominently and cephalopods also rate high. Most of the stomachs examined from this region are, however, empty or the food remains are too digested for identification.

Though in any one individual there is a tendency for the food items to be uniformly of one species, mixtures of various species are not infrequent. There may be mixtures of fish and Crustacea and of fish with cephalopods. An extreme example of a tuna with a heterogeneous assortment of food items was a 26-lb specimen caught in Shark Bay, W.A., in August 1943. The following items were identified by G. P. Whitley:

NORTHERN BLUEFIN TUNA

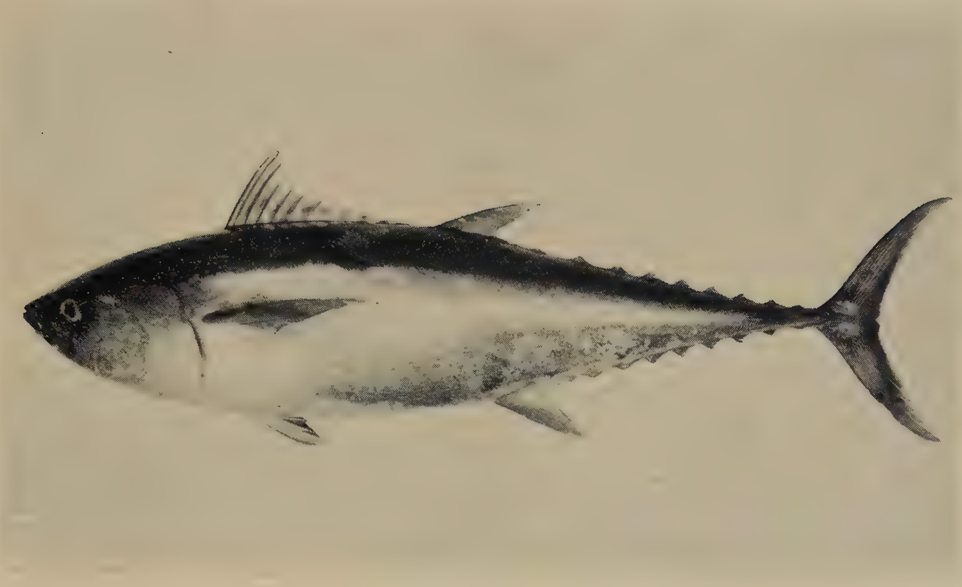

Fig. 1.—*Kishinoella tonggol* (Bleeker). Large specimen, Port Hacking, N.S.W.; length, 95·5 cm; weight, about 25 lb. Photo, A. Proctor.

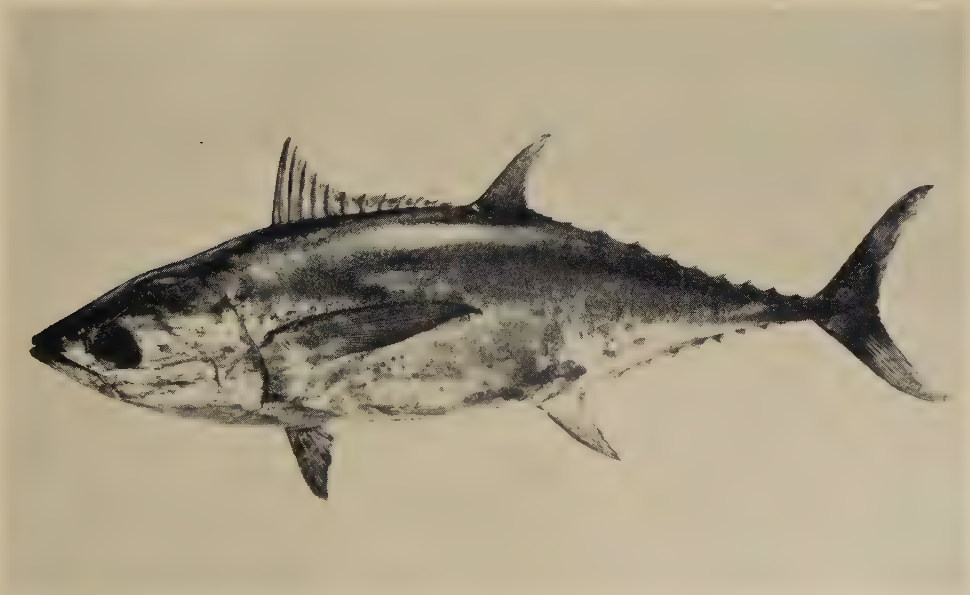

Fig. 2.—*K. tonggol*, small specimen, Java; length, 47·6 cm; weight, 4 lb. Photo, A. Proctor.

1 garfish, headless, *c.* 280 mm total length;
3 silver fish (*Gerres ovatus* Günther), 126, 112, and *c.* 80 mm;
2 squid, 56 and 125 mm;
8 stinkfish (*Calliurichthys* sp.), 97-143 mm;
1 flathead (*Suggrundus parilis*), 100 mm;
18 anchovies (Engraulidae), 37-84 mm;
3 gobies (Gobiidae, sp. A), 52-57 mm;
2 gobies (sp. B), 35 mm;
1 parrot fish (*Coris auricularis* (C. & V.)), 125 mm;
1 herring (? *Clupalosa lippa* (Whitley)), 88 mm;
1 small fish (? *Lepadichthys sandaracatus* Whitley), 29 mm.

VII. ACKNOWLEDGMENT

For assistance in the statistical treatment and interpretation of the results I am indebted to Mr. N. Stenhouse, Division of Mathematical Statistics, C.S.I.R.O., whose office made the machine computations.

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THE MARINE ALGAE OF KANGAROO ISLAND

IV. THE ALGAL ECOLOGY OF AMERICAN RIVER INLET

By H. B. S. Womersley*

[*Manuscript received July* 4, 1955]

Summary

An account is given of the marine ecology of American River inlet on the north coast of Kangaroo Island, S.A. The plant and animal associations are described, with emphasis on the marine algae, and an attempt is made to relate levels of zones to tidal means.

I. Introduction

American River is a tidal inlet extending from the north coast of Kangaroo Island, S.A., to within half a mile of the south coast. The term "river" is a misnomer as the amount of fresh water entering the lagoons is negligible.

From a narrow neck about a quarter of a mile wide at the mouth, the inlet widens into several extensive lagoons, measuring some 5 miles in a north-south direction and 4 miles from west to east (Plate 1, Fig. 1). From the opening a narrow channel (2-3 fm deep) extends past Muston jetty and into Pelican Lagoon, where several small islands occur (see Fig. 1). The channel is bordered by sandy or muddy tidal flats which are covered by less than 2 ft of water at low tide, with the shoreward parts usually exposed. The drop-off over the flats is very gentle, sometimes less than 1 ft on a flat 600 ft wide. Parts of Pelican Lagoon are from 2 to 5 fm deep (shown by denser dotting in Fig. 1).

In paper I of this series (Womersley 1947) a brief preliminary account of American River inlet was given. The basic terminology used in describing the zonation of organisms on the coasts of Kangaroo Island was outlined, and this has been further discussed and slightly modified in a separate paper (Womersley and Edmonds 1952). The terminology adopted is similar to that found satisfactory by many marine ecologists, and differs from that of Stephenson and Stephenson (1949) in retaining the older use of littoral and mid littoral, and thus avoiding illogical nomenclature for the zones. "Sublittoral fringe" is used in the original sense of Stephenson and Stephenson, and as this is then a term of restricted (though useful) application, the more widely applicable term "upper sublittoral" is used for the zone from mean low tide level downwards when the dominant(s) extend well below lowest tide level. Bennett and Pope (1953) have used for Victorian coasts virtually the same scheme as supported by Womersley and Edmonds, though relating their scheme to that of Stephenson and Stephenson. Gislén (1930), Feldmann (1951), and Sundene (1953) use essentially the same scheme as that adopted here. The new terminology of Stephenson and Stephenson is supported in large measure by Chapman and Trevarthen (1953) and Guiler (1953), who, however, give no adequate reasons for changing the older and reasonably well-established nomenclature of zones.

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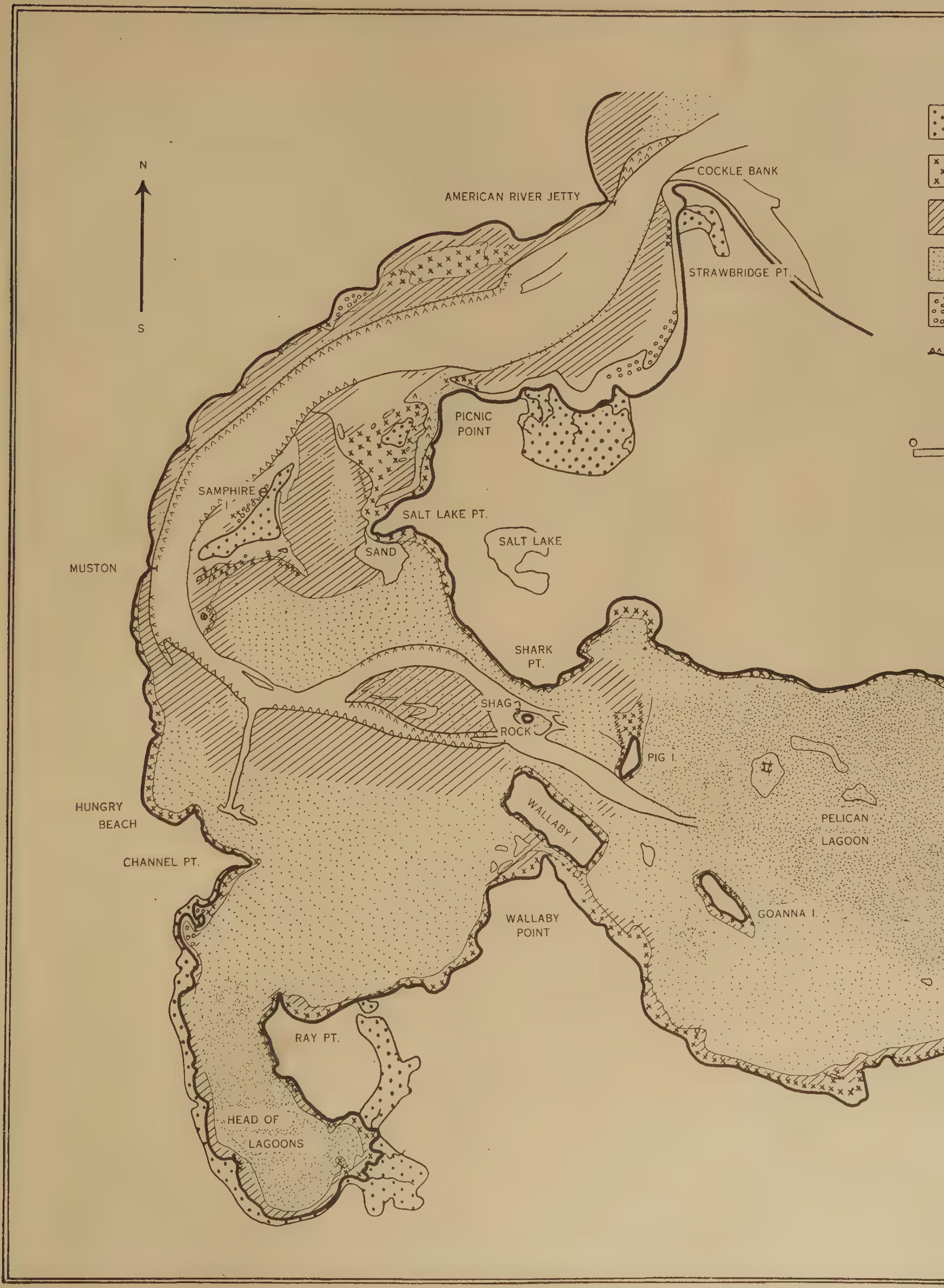
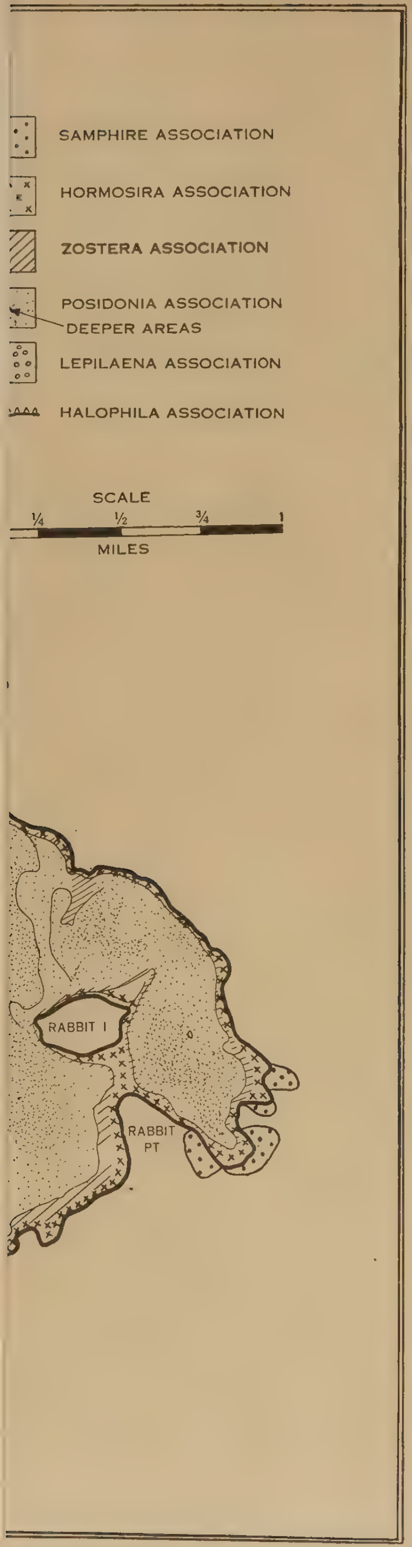

N
S
AMERICAN RIVER JETTY
COCKLE BANK
STRAWBRIDGE PT.
PICNIC POINT
SAMPHIRE I.
SALT LAKE PT.
SALT LAKE
SAND
MUSTON
SHARK PT.
SHAG ROCK
PIG I.
WALLABY I.
PELICAN LAGOON
HUNGRY BEACH
CHANNEL PT.
GOANNA I.
WALLABY POINT
RAY PT.
HEAD OF LAGOONS
0

Fig. 1.—Map of American River inlet. In delimiting the *Posidonia* association, denser dotting is used for the de graph), and lighter dotting for shallow areas where the leaves are at or near to the surf


SAMPHIRE ASSOCIATION
HORMOSIRA ASSOCIATION
ZOSTERA ASSOCIATION
POSIDONIA ASSOCIATION
DEEPER AREAS
LEPILAENA ASSOCIATION
HALOPHILA ASSOCIATION
SCALE
¼
½
¾
1
MILES
RABBIT I
RABBIT PT

per areas (as shown in an aerial photo-
ce at low tide.

Chapman and Trevarthen (1953) also believe there is no advantage in correlating zonation on different types of substratum under one terminology.

At American River inlet two types of substratum occur: sandy mud in the lower tidal levels and (sometimes) rock at the upper levels. Here it is obviously necessary to use one scheme for both types of substratum. It is interesting also that Dahl (1952) has found that sandy beaches can be subdivided (based on the organisms present) into three horizontal belts to which he applies the names of Stephenson and Stephenson (the older nomenclature applies just as well).

In December 1949 the South Australian Harbours Board established an automatic tide gauge at American River jetty. The continuous tidal records from this have made possible an attempt to correlate the zones of algae and animals with tidal fluctuations, and to define critical tidal levels.

The entire coast of the inlet has been examined during the survey, at all seasons of the year. From these detailed observations broader generalizations have been drawn, and it is clear that while the basic zones of organisms are quite stable, minor species of the sublittoral fringe and lower littoral may vary in their presence and distribution in different seasons. Sufficient boat traverses have been made across the deeper parts of the lagoons to show the dominant organisms.

The names of the islands in Pelican Lagoon are those used locally, but the more prominent points around the lagoon have been given names for convenience as there seem to be no locally used names.

This paper also deals briefly with those animals which form a conspicuous and important part of the zonation. The animal life of the inlet is rich, and a detailed zoological survey would be of great interest. Taxonomic references for the algal species are given by Womersley (1950).

II. The Environment

(*a*) *The Substratum*

The tidal flats are composed mainly of black mud, 4-10 in. deep, often with a layer of sand on top. Near the shore the mud or sand layer is shallower, sometimes with exposed rock. The mid and upper parts of the littoral zones consist of either sandy beach, samphires, or the base of low rocky cliffs of calcareous sand rock (see Plate 1, Fig. 2; Plate 2, Figs. 1 and 2).

Where rock is exposed marine algae occur directly attached to it, but wherever there is a layer of mud the algae grow on either molluscs or pebbles in the mud (e.g. *Hormosira* on *Brachyodontes*) or on the marine angiosperms which cover most of the tidal flats.

The channel supports plant growth mainly on the upper sides, as the bottom consists of loose shells and the current (up to 2½ knots) prevents a stable substratum. Occasional patches of rock near Muston and American River jetty allow the development of some brown algae, mainly *Sargassum biforme* Sonder.

(*b*) *The Tides*

The continuous tidal curves obtained at American River jetty were graphed in weekly periods for 12 months from January 1, 1950, and from them mean sea-level and means of the higher and lower daily tides were calculated (see Table 1). Several 24-hr surveys carried out at American River jetty, at Muston, and in Pelican Lagoon simultaneously show that the tides are of the same form throughout the inlet and of very nearly the same amplitude (see Womersley 1947, p. 232 and Fig. 2). Differences in amplitude at American River jetty and Pelican Lagoon are usually less than 2 in. in a rise of 3½-4 ft and this difference may sometimes be due to wind effect.

The tidal range at American River jetty is usually 3·9-4·3 ft (extremes of 3·4 and 4·8 ft) for spring tides and 3·0-3·6 ft (extremes of 2·0 and 3·75 ft) for neap (dodge) tides, but the range is extremely variable.

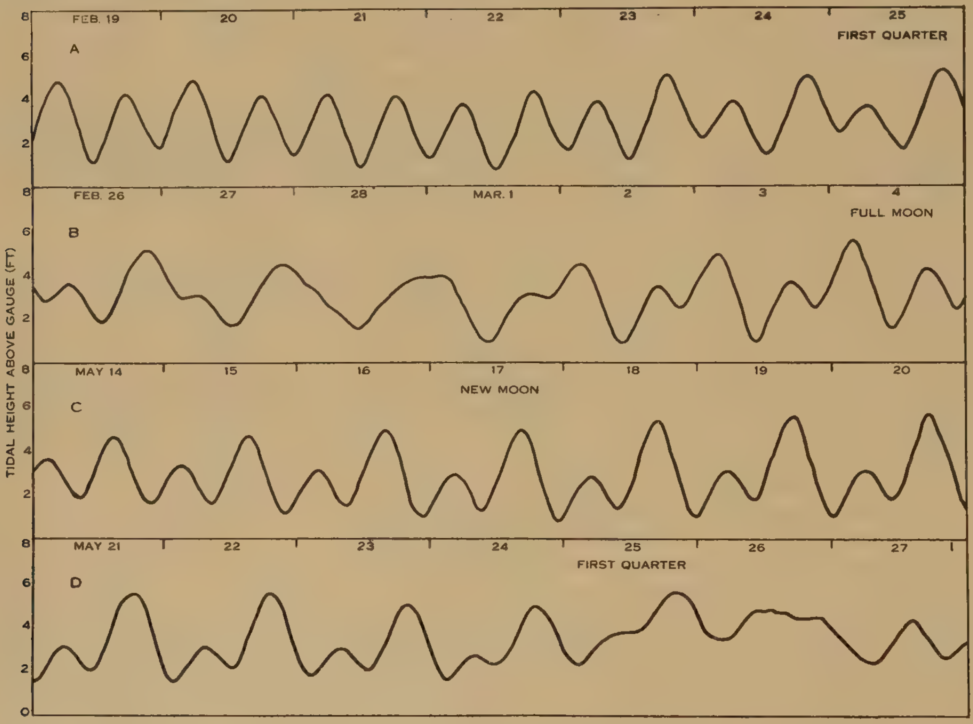


Fig. 2.—Representative tidal curves from American River inlet, 1950. *A*, typical spring tides with almost equal amplitude (semi-daily type). *B*, neap tides with one tide per day over 2-3 days. *C*, spring tides with marked diurnal inequality (mixed type). *D*, dodge (neap) tides showing "dodging effect" on May 26.

The tides at Muston are ½-1 hr behind, and in Pelican Lagoon up to 2 hr behind, the tides at American River jetty.

An examination of the tidal curves for 1950 shows their great irregularity compared with those from many other regions (e.g. compare the curves given by Doty (1946, Fig. 1) for the Pacific Coast of the United States of America). Tides in many localities in South Australia are noted for their irregularity, both at one locality and between different localities. Some examples of the American River inlet tides are given in Figure 2. Curves *A* and *C* are of spring tides, curves *B* and *D* of neap (dodge) tides.

At spring periods the tides are semidiurnal, but the two daily tides may be almost equal in amplitude ("semi-daily")* (Fig. 2*A*) or markedly unequal ("mixed") (Fig. 2*C*), or intermediate between these two types. The highest tides usually occur between 0 and 3 days after new or full moon, but may occur at other times. The three highest tides recorded during 1950 occurred at full moon, 1 day after, and 2 days before full moon. The lowest tides of the spring period rarely occur at the same time as the highest tides, but are most irregular. In fact, the lowest tides more often occur at the "dodge" periods.

At the neap period the "dodge" effect occurs, but is shown in different ways. In most cases only one tide per 24 hr occurs over 2-4 days at the neap period (Fig. 2*B*), but occasionally two tides of lesser amplitude occur; on other occasions a more typical "dodging" tide occurs, with the water level remaining almost stationary for 6-10 hr (Fig. 2*D*). When the single tide occurs, the low level is usually lower than tides before and after, whilst the high may be nearly as high as some spring tides. The neap period occurs at varying times, from a day before the first and third quarters of the moon to 4 or 5 days after.

Little is known of the cause of the dodge effect, which is largely confined to the gulf region in South Australia. The hypothesis of Chapman (1924) is that during the neap period the sun and the moon, together with other tide-producing forces, exert almost equal but opposite effects, one nullifying the other. It has been suggested that the abnormally large effect of the sun is due to the synchronizing of the natural period of swing of the basin of water between Australia and Antarctica with the period of the tide-producing forces.

A partial cause of the tidal irregularities is wind. Strong westerly winds across Investigator Strait (26 miles wide) raise the sea-level generally in the gulf region, as the water is not forced out through Backstairs Passage (10 miles wide) to the same extent. This results in higher tides at American River inlet. A south wind tends to have the opposite effect.

Even when the tide is ebbing or flowing relatively strongly, it may be very irregular over short periods owing to seiche effects, sometimes dropping or rising as much as 4 to 6 in. from the general trend of the tide.

Owing to these irregularities, it was found to be meaningless to average such levels as high and low water of spring and neap tides. Means of the following levels could, however, be calculated and are given below (Table 1):

Mean of the higher of the two daily high waters (M.H.H.W.),
Mean of the high waters (M.H.W.),
Mean of the lower of the two daily high waters (M.L.H.W.),
Mean sea-level (M.S.L.),
Mean of the higher of the two daily low waters (M.H.L.W.),
Mean low water (M.L.W.),
Mean of the lower of the two daily low waters (M.L.L.W.).

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* See Marmer 1951.

These levels are similar to those used by Doty (1946), though not so comprehensive. At the neap periods, when only one high and one low tide occurred, L.H.W. and H.L.W. were omitted. Records for January, February, and April are incomplete, as about 1 week's readings were not taken in each month. Curves from the corresponding period about 29 days later were interpolated in each case.

Table 1

TIDAL DATA, AMERICAN RIVER JETTY, 1950

All tidal figures (ft) are based on, or corrected to, the Harbours Board tide gauge at American River jetty. Highest high water in 1950, 7·1 ft. Lowest low water in 1950, —0·1 ft

Month	M.H.H.W.	M.H.W.	M.L.H.W.	M.S.L.	M.H.L.W.	M.L.W.	M.L.L.W.
January	4·79	4·09	3·27	2·90	2·21	1·66	1·25
February	4·35	3·89	3·40	2·64	1·77	1·28	0·89
March	4·35	3·85	3·32	2·64	1·77	1·34	0·99
April	4·59	3·95	3·28	2·82	1·79	1·52	1·27
May	5·13	4·21	3·13	3·13	2·00	1·81	1·66
June	5·33	4·32	3·21	3·29	2·47	2·03	1·73
July	5·16	4·38	3·41	3·16	2·36	1·94	1·61
August	4·94	4·47	3·83	3·11	2·16	1·78	1·49
September	4·95	4·47	3·86	3·18	2·20	1·81	1·48
October	4·89	4·20	3·45	3·07	2·07	1·81	1·57
November	4·89	4·12	3·18	3·07	2·07	1·85	1·66
December	4·81	3·85	2·99	2·82	2·14	1·69	1·28
Mean, 1950	4·85	4·15	3·35	2·99	2·08	1·71	1·41

Table 1 gives various means calculated for each month during 1950. All show the same yearly trend, being higher during the winter months and lowest during summer months. Mean sea-level, for instance, was lowest during February and March 1950 (2·64 ft), and highest in June (3·29 ft), the difference being 0·65 ft. The means for January (higher than December and February) are possibly higher than normal, perhaps due to northerly winds during the month. Very low tides during January are frequent, and from experience the mean sea-level would be expected to be as low as that of February.

General features of the tides at American River inlet are as follows:

(i) The higher of the two daily high tides occurs in the early hours of the morning (often 2-7 a.m.) during the summer months (November to February) but changes over to the afternoon (12 noon-5 p.m.) during the winter (April to September). March and late September-October are the "change over" months.

(ii) The lower of the two daily high tides is virtually the opposite of the highest: between 3 and 6 p.m. from October to February, and between 3 and 7 a.m. from April to August.

(iii) The lower of the two daily low tides occurs in the middle of the day (10 a.m.-2 p.m.) from late November to April, and in the middle of the night (8 p.m.-4 a.m.) from June to October, with April-May and October-November as "change over" months.

(iv) The higher of the two daily low tides is opposite to the lower, occurring in the middle of the night from November to April and in the middle of the day from May to September.

(*c*) *Exposure to Air*

The percentages of the total time during which different heights are covered by water are given in Table 2 for each month of 1950. The values vary considerably from month to month, and even more for weekly periods within each month. This is a direct result of the tidal irregularities. The heights for which exposure to air has been calculated correspond to the main changes between zones and to tidal levels given in Table 1 which lie within a zone. Table 2 will be referred to later when dealing with critical levels.

The degree of exposure to the air at any particular level is greater during summer months than during the winter. This, together with the much higher summer temperatures, means that the severest environmental conditions will occur when a hot day in summer coincides with a very low tide. Such critical summer day conditions are possibly of greater importance than any tidal means in determining the levels at which any particular alga can grow.

(*d*) *Wind*

The prevailing winds are from south to west, with some northerly winds in summer. The effect of westerly winds in causing generally higher tides has been referred to above. Within the inlet mild breezes have little effect except to cause waves in the channel. However, on one area of the north coast of Pelican Lagoon the water is 4 ft deep or more at the base of vertical cliffs, and even a light southerly wind (having passed over 2 or 3 miles of water) causes continuous lapping of waves on the base of the cliffs. This results in some 200 yd of coast which is more allied to other areas of the north coast of Kangaroo Island than to the rest of American River inlet. At Salt Lake Point also, wave action is more pronounced, and some organisms characteristic of the "sheltered rocky coast subformation" (see Womersley 1947) occur here.

Strong winds (especially in late winter) will cause wave action along the edge of the channel sufficient to remove many epiphytic algae from their angiosperm hosts.

(*e*) *Wave Action*

Wave action is completely dependent on wind; on the whole it is slight, often almost absent. This is one of the main causes of the distinctiveness of the American River inlet. Several minor exceptions have been mentioned in Section II(*d*).

(*f*) *Water Turbidity*

The water carries a certain amount of fine suspended mud, especially in and near the channel when strong tides are running. The bottom of the channel (2-3 fm deep) can only be seen when there is no tidal current. The turbidity doubtless

TABLE 2

EXPOSURE OF ZONES TO AIR: PERCENTAGES OF TOTAL PERIOD DURING WHICH EACH LEVEL WAS COVERED

Month / Level:	Upper *Bostrychia*	M.H.H.W.	M.H.W.	M.L.H.W.	M.S.L.	Upper *Hormosira*	M.H.L.W.	M.L.W.	M.L.L.W.
Height (ft):*	5·3	4·85	4·15	3·35	3·0	2·55	2·1	1·70	1·40
January	3	6	14	32	43	58	75	85	92
February	0	2	9	28	38	51	66	78	85
March	0	2	10	25	35	50	66	77	86
April	2	5	13	28	40	57	71	82	91
May	4	9	21	38	48	62	81	91	96
June	8	13	23	40	53	70	86	93	98
July	6	11	22	40	50	68	80	88	93
August	3	9	21	40	52	65	79	87	93
September	3	7	20	42	52	69	81	90	96
October	2	6	18	35	49	65	79	91	95
November	4	8	17	33	46	64	80	91	96
December	2	6	14	28	36	52	75	85	91
Mean, 1950	3	7	17	34	45	61	77	87	93

* Based on American River tide gauge.

has some effect on the organisms, and is possibly a partial cause of the yellow, grey, or brownish colour of most of the Rhodophyceae, in contrast to the brighter red colour of deeper- and cleaner-water forms. Many algae have a fine coat of mud or silt over their thalli.

(*g*) *Temperature*

(i) *Air Temperatures.*—Those given for Kingscote (Womersley 1947, p. 234), probably apply fairly well at American River inlet, though cool southerly breezes would have greater effect in the inlet. The Kingscote temperatures show a range (monthly averages) from 8·7-14·2° C in July to 15·6-22·7° C in February. Probably more important than mean temperatures, however, are occasional very high temperatures (up to 100° F) in summer, which may cause extreme conditions during low tides on the tidal flats.

(ii) *Sea Temperatures.*—These range from about 10° C on the tidal flats and channel on cold winter days to 23° C in the channel and over 30° C on shallow flats on hot summer days. The annual, and also the daily range in summer, is great, and doubtless prevents some algal species from occurring in the inlet. The annual range in temperature is three to five times as great as on the south coast of Kangaroo Island.

(*h*) *Shade*

Most of the intertidal zones are exposed to full sunlight except the upper littoral (occasionally also the mid littoral) which may occur at the base of low cliffs. The upper littoral is often completely shaded, or has many shaded hollows and crevices which allow the development of the algae *Bostrychia simpliciuscula* Harvey and *Gelidium pusillum* (Stackhouse) Le Jolis. In the shade under large samphires (*Arthrocnemum arbuscula* (R. Brown) Moq.) at about high tide level, mats of *Chaetomorpha capillaris* (Kützing) Borgesen as well as *Bostrychia* and *Gelidium* occur.

(*i*) *Salinity*

The following ranges in salinity were obtained during a 24-hr survey on January 20-21, 1946: American River jetty, 35·9-36·1‰; Muston jetty, 35·9-36·3‰; Pelican Lagoon 37·0-37·2‰. The higher salinity in Pelican Lagoon is due to increased evaporation in summer from the relatively shallow and isolated lagoons.

The amount of fresh water entering the inlet is negligible except after heavy rain, when a few creeks may flow, and even then they exert only a minor local effect. On rare occasions very heavy rain during low tides may lower the chlorinity on the tidal flats. During January 1946, over 5 in. of rain fell in 4 days, and at one stage the salinity on the tidal flats was 30·2-31·8‰. For several days afterwards there was a noticeable stench of decay, apparently from algae killed by this low salinity.

(*j*) *Oxygen*

Oxygen saturation of the water varies considerably during the day and night. Values of 130 per cent. saturation during the day in summer are common, dropping to 50-60 per cent. at night. Broken water tends to keep this latter value higher.

In shallow water over dense algal growth, saturation values as high as 200 per cent. occur.

The oxygen in the water is controlled, firstly, by the plants and animals present, and secondly, by wave action and broken water, which tend to keep the saturation nearer 100 per cent. Oxygen saturation is rarely, if ever, likely to be a controlling factor in algal growth or distribution in this type of habitat.

(*k*) *Phosphate*

Samples taken in January 1946 showed varying phosphate values, mostly between 2 and 16 parts per 1000 million of phosphate phosphorus. One sample from Pelican Lagoon contained 63 parts per 1000 million, but this was probably a local effect due to bird colonies.

(*l*) *Nitrate*

In six samples taken at the same time as the phosphate samples no nitrate could be detected. Low nitrate is usual in South Australian waters. Both low phosphate and low nitrate are due largely to the absence of any large rivers in the region, but at American River inlet may also be due to a high phytoplankton population.

On Shag Rock in Pelican Lagoon, *Gayella polyrhiza* Rosenvinge occurs plentifully on rocks where shags roost. As in many localities in other countries, *Gayella* (and *Prasiola*) occurs where there is nitrogenous excrement from birds.

III. Zonation in Relation to Tidal Levels

Zonation of algae and animals is relatively constant throughout the inlet, especially at or below the mid-littoral level where tidal flats always occur. However, two types of coast are found within the inlet, resulting in differences at the upper littoral and supralittoral levels:

(1) Rocky cliffs (6-30 ft high) descending to the mid littoral, with shaded hollows at their base (Fig. 3, section *B*; Plate 2, Fig. 2). Cliffs occur around most of the islands in Pelican Lagoon, on much of the north side of Pelican Lagoon, and as outcrops elsewhere in the inlet.

(2) Areas where the tidal flats shelve gently through the littoral, with samphires or shelly beaches in the upper littoral and supralittoral (Fig. 3, section *A*; Plate 1, Fig. 2). Most of the coast from American River jetty to Muston and on to the head of the lagoons is of this type, while smaller areas occur in Pelican Lagoon. The larger areas of samphires are shown in Figure 1, but a fringe of samphires occurs around most of the coast where there are no rocky cliffs.

(*a*) *The Typical Zonation*

The typical zonation where cliffs occur is shown in Figure 4 (see also Fig. 3, section *B*).

(i) *The Supralittoral.*—The supralittoral is generally almost bare of macroscopic organisms. Occasional *Bembicium melanostoma* Philippi may extend into it, and

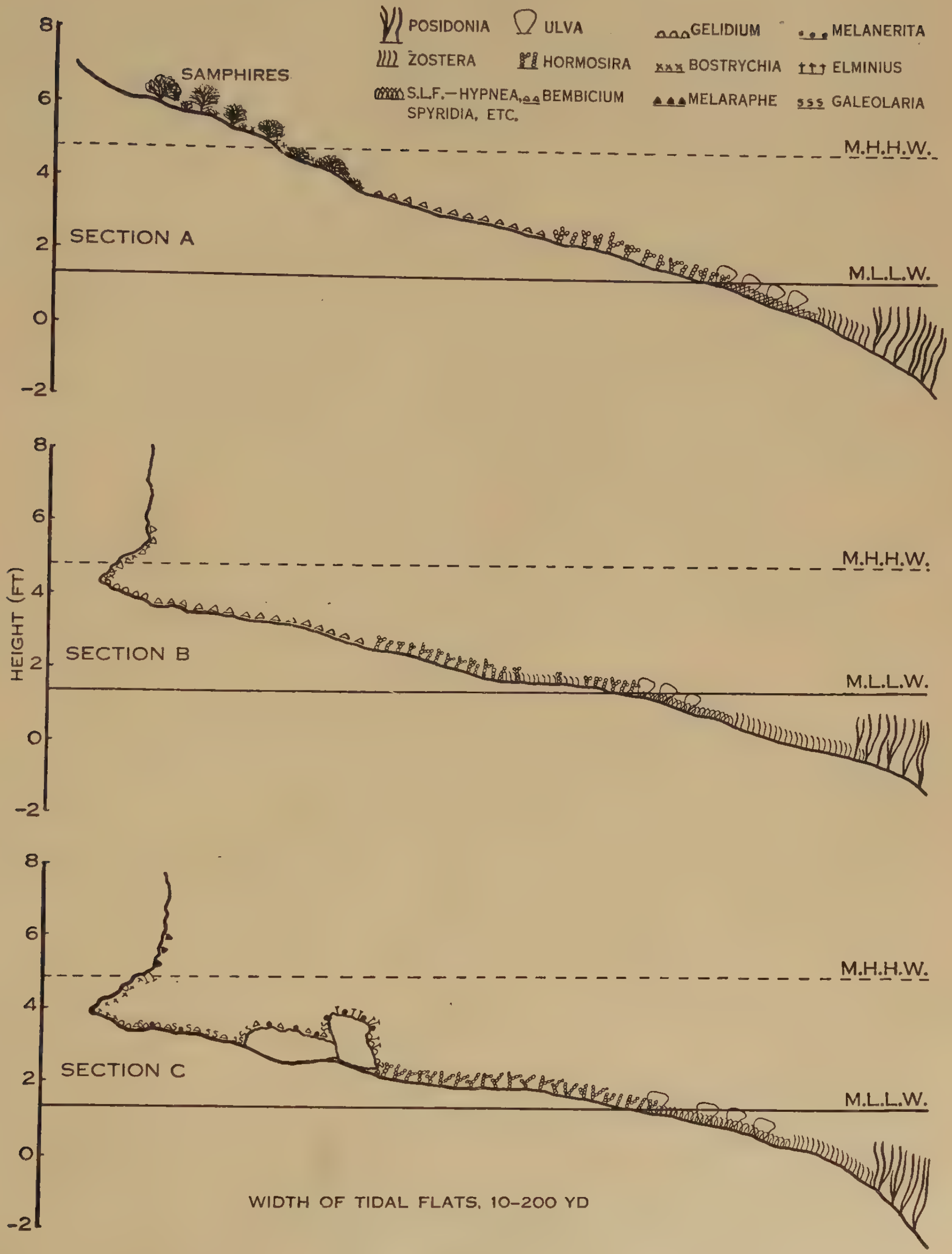
POSIDONIA
ULVA
GELIDIUM
MELANERITA
ZOSTERA
HORMOSIRA
BOSTRYCHIA
ELMINIUS
S.L.F.—HYPNEA, SPYRIDIA, ETC.
BEMBICIUM
MELARAPHE
GALEOLARIA
SAMPHIRES
SECTION A
SECTION B
SECTION C
M.H.H.W.
M.L.L.W.
HEIGHT (FT)
8
6
4
2
0
-2
WIDTH OF TIDAL FLATS, 10-200 YD

Fig. 3.—Zonation diagrams for representative coasts in American River inlet. Section *A*, sandy beach with samphires at rear of tidal flats. Section *B*, low cliffs at rear of tidal flats. Section *C*, an area on the north coast of Pelican Lagoon subject to greater wave action, resulting in *Melaraphe*, *Elminius*, and *Galeolaria* occurring at higher levels.

the lichen *Verrucaria microsporoides* Nyl. occurs in the lower part as tiny black spots which in some places give a dark appearance to the rock. In restricted areas of greater wave action, *Melaraphe unifasciata* Gray may occur in small numbers.

(ii) *The Littoral.*—For convenience the littoral may be divided into three zones.

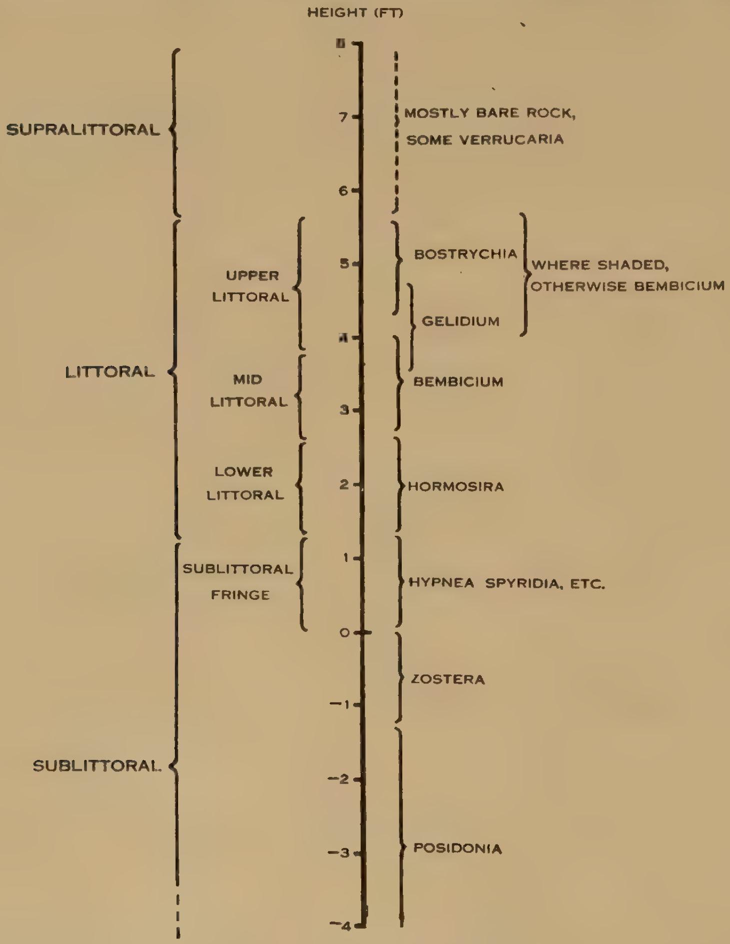
HEIGHT (FT)
8
7
6
5
4
3
2
1
0
−1
−2
−3
−4
SUPRALITTORAL
LITTORAL
SUBLITTORAL
UPPER LITTORAL
MID LITTORAL
LOWER LITTORAL
SUBLITTORAL FRINGE
MOSTLY BARE ROCK, SOME VERRUCARIA
BOSTRYCHIA
GELIDIUM
WHERE SHADED, OTHERWISE BEMBICIUM
BEMBICIUM
HORMOSIRA
HYPNEA SPYRIDIA, ETC.
ZOSTERA
POSIDONIA

Fig. 4.—Scheme of the typical zonation in American River inlet, showing relation of organisms to tide levels.

(1) *Upper Littoral.*—On rock not in shade, the upper limit of the littoral can probably best be placed at or just above M.H.H.W. (about the 5·0 ft level). The chief organism here is the mollusc *Bembicium melanostoma*, which extends upwards from the mid littoral. In some places *Verrucaria* darkens the rock.

In shaded places, *Bostrychia simpliciuscula* occurs from 5·4 to 4·5 ft, and *Gelidium pusillum* from 5·0 to 3·4 ft. The levels of these algae are as much dependent on shade as on tidal exposure, and are therefore rather variable. *Gelidium* tends to occur in less shaded places than *Bostrychia*, sometimes where direct sunlight falls on it for short periods.

(2) *Mid Littoral.*—This zone is dominated by *Bembicium melanostoma* (Plate 4, Fig. 1), which is one of the few organisms able to withstand the exposure to air and to direct sunlight of the zone. The lower limit lies at the 2·5-2·6 ft level; above about 3·5 ft on unshaded rock *Bembicium* becomes less common, but individuals can be found well above this level. The bivalve *Modiolus areolatus* Gould may form patches in the mid littoral and become co-dominant with *Bembicium*. Small communities of *Enteromorpha clathrata* (Roth) J. Agardh may also occur here.

(3) *Lower Littoral.*—This zone is dominated by *Hormosira banksii* (Turner) Decaisne throughout most of the inlet. Its limits are from 2·5-2·6 to 1·3-1·4 ft; the lower limit corresponds closely to M.L.L.W.

(iii) *The Sublittoral.*—The littoral-sublittoral boundary lies at the junction of the *Hormosira* zone and a zone of red algae dominated by *Hypnea musciformis* (Wulfen) Lamouroux and *Spyridia biannulata* J. Agardh. The upper limit is at 1·2-1·4 ft (M.L.L.W.). This zone extends down for only a short distance, rarely more than the 0·0 ft level, though isolated plants may occur lower. This *Hypnea-Spyridia* zone may be referred to as the sublittoral fringe in view of its restricted vertical range.

Zostera muelleri occurs from about 0·5 to —3 ft or lower, though in some areas it occurs as high as 2·0 ft. Growth is best where it is never exposed.

Posidonia australis forms dense "meadows" from —0·5 ft downwards, especially in deeper water in Pelican Lagoon.

(*b*) *Zonation where Cliffs Do not Occur*

This is essentially similar to the zonation described above, except that samphires (*Salicornia australis*, *Arthrocnemum arbuscula*) occur in the upper littoral (3·5 ft upwards) and supralittoral (Fig. 3, section *A*; Plate 1, Fig. 2; Plate 2, Fig. 1). The roots and lower stems of these plants are flooded at high tides, and low plants may be completely covered. In the shade of the samphires, *Bostrychia simpliciuscula* and *Chaetomorpha capillaris* occur, with *Gelidium pusillum* on the lower stems.

(*c*) *Variations on the Typical Zonation*

On Shag Rock in Pelican Lagoon, *Gayella polyrhiza* grows as mats on the rock in the supralittoral where shag excrement is plentiful. Only occasional spray reaches this zone.

At Salt Lake Point, wave action becomes moderate as the prevailing south-west wind blows across 2 miles of water. Owing to the wave action the zones are slightly elevated, and several species occur here which are more characteristic of the sheltered rocky coast subformation (see Fig. 3, section *C*). Zones below the mid littoral are typical, but in the mid littoral serpulid worm tubes (*Galeolaria caespitosa* Savigny) occur at the base of the cliffs and on rocks, while in the upper littoral the barnacle *Elminius modestus* Darwin is common on rock faces exposed to the waves (i.e. facing the south-west). Scattered *Melanerita melanotragus* Smith also occur. Nevertheless, *Bembicium* is dominant in the mid littoral generally. In the supralittoral a few *Melaraphe unifasciata* occur. The lichen *Verrucaria* is also more prominent in the upper littoral and lower supralittoral.

An area of the central north coast of Pelican Lagoon, some 300-400 yd long, consists of cliffs dropping vertically to below low tide level, with no intertidal flat. Here wave action is greater than elsewhere in the inlet, owing to deeper water at the base of the cliffs and also to stronger wind action across Pelican Lagoon. As a result of the stronger wave action, the zonation here is more like that outside American River inlet. The organisms mentioned in the previous paragraph occur here, and in addition the sublittoral fringe is dominated by the brown alga *Cystophora polycystidea* Areschoug. This alga is not found elsewhere in the inlet, but is characteristic of the north coast of Kangaroo Island. *Hormosira* occurs as a very compressed zone (with dense tufts of *Jania* sp. amongst it) on a small rocky ledge in the lower littoral. *Peyssonnelia gunniana* J. Agardh and a lithothamnion growing on *Brachyodontes erosus* Lamarck are other unusual components of the sublittoral fringe.

This area of coast is really a fragment of the sheltered rocky coast subformation within American River inlet, and demonstrates the fundamental importance of wave action in determining the algal formations.

(*d*) *Critical Levels*

Doty (1946), Beveridge and Chapman (1950), and others have found that certain tidal levels ("critical levels") correspond to the breaks between zones on the shore. An attempt has been made to relate the zones at American River inlet to tidal levels, but owing to the relatively small tidal rise and great irregularity in the tides, the attempt has met with only limited success.

Table 1 gives the means of tidal levels which were calculated. If these are compared with the breaks between zones (Fig. 4), it is evident that two levels can probably be termed critical; these are M.L.L.W., which is very close to the *Hormosira*-sublittoral fringe break, and M.L.H.W., which corresponds to the lower limit of *Gelidium*. The other tidal levels in Table 1 come within zones and do not appear to be critical.

In the upper littoral, the determining factor is shade rather than tidal fluctuations, so that close correlation of *Bostrychia* and *Gelidium* limits with tides would not be expected.

There remains, however, one clear-cut level that cannot at present be related to tidal levels, i.e. the upper limit of *Hormosira*, which falls about half-way between M.H.L.W. and M.S.L.

The degree of exposure to air is probably an important determining feature of the zonation, and is directly dependent on tidal fluctuations. Table 2 gives monthly percentage times during which certain levels are covered, and the following are the limits for the main intertidal zones:

The upper littoral (*Bostrychia* and *Gelidium*) is covered between 3 and 25 per cent of the time (monthly extremes, 0-8 and 16-32 per cent.)

The mid littoral (*Bembicium*) is covered between 25 and 61 per cent. of the time (monthly extremes, 16-32 and 50-70 per cent.).

The lower littoral (*Hormosira*) is covered between 61 and 93 per cent. of the time (monthly extremes, 50-70 and 85-98 per cent.).

The sublittoral fringe (*Hypnea-Spyridia*) is covered for more than 93 per cent. of the time (monthly extremes, 85-98 per cent.).

The monthly variation (and to an even larger extent the daily variation) in exposure to air of the different zones is very considerable. It seems impossible to consider any particular organism as sharply limited by a certain degree of exposure, partly no doubt because of the importance of the other factors, such as shade and, in *Hormosira*, the presence of reservoirs of water in each vesicle.

IV. The Plant and Animal Associations

The more extensive plant associations of the tidal flats are shown in Figure 1, which was drawn from aerial photographs. Owing to the scale, it is not possible to show associations higher (i.e. nearer the shore) than the *Hormosira* association, as they form comparatively narrow bands. For the same reason the sublittoral fringe association of *Hypnea-Spyridia* is not shown, but it occurs between *Hormosira* and *Zostera*, often mixing with the latter.

The tidal flats are very largely covered with plant growth, but there are a few sandy areas which do not provide a suitable substratum for many algae or any of the angiosperms. These sandy areas are left unshaded in Figure 1, but they may bear communities of *Ectocarpus confervoides* (Roth) Le Jolis and *Polysiphonia patersonis* Sonder, both growing on cockle-shells buried in the sand.

Most of the tidal flats are covered by marine angiosperms. These are the only plants which can colonize sandy or muddy areas, but they provide a substratum on which many small algae can grow.

The main plant and animal associations will be described as they occur from the supralittoral downwards. Species for which the seasonal distribution is not given almost certainly occur throughout the year. Variations from the typical zonation have been described previously, so only the main associations will be described here.

(*a*) *The Supralittoral*

(i) Gayella polyrhiza *Association.—G. polyrhiza* occurs only on Shag Rock, where there is excrement from a shag (cormorant) colony. It forms thin green mats over the rock and is best developed during winter. Previously (Womersley 1947, p. 239) it was reported as *Prasiola*, and like this closely related genus it is dependent on an increased supply of nitrogen. *Gayella* on Shag Rock is rarely wet by spray and is as much a terrestrial as a marine alga.

(*b*) *The Littoral*

(i) Bostrychia simpliciuscula *Association.—Bostrychia* occurs only in well-shaded places of the upper littoral, usually as scattered patches but frequently lining the floor and sides of small caverns (6-8 ft long) in the base of the cliffs. It forms soft, dark brown mats, $\frac{1}{2}$-1 cm thick (Plate 3, Fig. 1). *Bostrychia mixta* Hooker & Harvey sometimes occurs mixed with *B. simpliciuscula*. The latter also occurs in the shade of the samphires, growing on mud or at the base of the plants.

(ii) Gelidium pusillum *Association.*—*Gelidium* occurs mainly below *Bostrychia*, but they often grow in the same area, though never intimately mixed. In growth habit they are very similar, the *Gelidium* being firmer and coarser than *Bostrychia* (Plate 3, Fig. 2). *Gelidium* grows in less-shaded places than *Bostrychia*, and may even receive direct sunlight for a short time each day.

Both the *Gelidium* and *Bostrychia* associations are relatively pure. Few other algae occur in the upper littoral zone, though *Cladophora repens* (J. Agardh) Harvey and *Chaetomorpha capillaris* are occasionally found. The mollusc *Bembicium melanostoma* occurs on otherwise bare rock between patches of *Gelidium* and *Bostrychia*, but mainly where exposed to sunlight.

During the winter months (July-November) *Porphyra umbilicalis* (Linnaeus) J. Agardh occurs in the lower *Gelidium* zone in Pelican Lagoon, on the more exposed rock. It is very variable in occurrence and seems to be absent in some years. The plants are not well developed, being only 6-12 cm high.

(iii) *The Samphire Association.*—Three species of Chenopodiaceae occur in the upper littoral and extend into the supralittoral, viz. *Salicornia australis*, *Arthrocnemum arbuscula*, and *Kochia oppositifolia* F. Muell. These are commonly called "samphires", and may occupy relatively large areas (see Fig. 1; Plate 1, Fig. 2; Plate 2, Fig. 1). *Salicornia australis* is the smallest (6-8 in. high) and occurs lowest. Some plants are completely submerged at high tide. *Arthrocnemum arbuscula* grows to a low bush 3 ft high, while *Kochia oppositifolia* grows to 5 ft in height and occurs highest on the shore. The roots and stems only of the latter two species are covered by high tides.

In the shade of the samphires *Bostrychia simpliciuscula*, *Gelidium pusillum*, and *Chaetomorpha capillaris* occur. *Bostrychia* and *Chaetomorpha* form loose, soft mats on the mud, while *Gelidium* grows mainly on the stems of the samphires. *Microcoleus chthonoplastes* (Mert.) Thuret (together with *Calothrix scopulorum* (Weber & Mohr) Agardh (?)) also forms mats on the mud.

(iv) Bembicium melanostoma* *Association.*—This mollusc dominates the mid littoral and extends up through the upper littoral, occurring on rock or mud (Plate 4, Fig. 1), throughout the inlet. On upper littoral rock not in shade, tiny black spots of the lichen *Verrucaria microsporoides* occur with *Bembicium*.

On flat areas of the mid littoral exposed to full sunlight, *Bembicium* is often the only macroscopic organism present, but on some flat rocky areas the bivalve *Modiolus areolatus* may be co-dominant. The *Modiolus* grow in small clumps on the rock, with scattered *Bembicium* between them. Beds of *Brachyodontes erosus* are also found in the mid littoral in a few places, though this bivalve is commoner in the lower littoral.

Algae are not common in the mid littoral, but the following occur:

Enteromorpha clathrata forms isolated patches, especially in slight hollows which remain moister at low tide, or near the base of the cliffs where there is some shade. Occasionally it occurs under the samphires. This alga is very variable in form and frequently stunted, but agrees with type II of Bliding.

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* This name includes a complex of forms. The one at American River inlet is sometimes known as *B. nanum*.

Rivularia nitida Agardh occurs as tiny scattered plants on rock on the south side of Pelican Lagoon, but is not common. Several other blue-green algae inhabit the mid littoral in the lagoons; *Isactis plana* (Harvey) Thuret grows on small rocks and old shells; *Palmophyllum crassum* (Nacc.) Rabenhorst (in the gloeocystoid state) forms irregular brownish blobs to 1 cm across, lying very loosely on the mud or rock; and *Lyngbya confervoides* Agardh forms flat mats which become very thin when dry and peel off readily. In a few small areas *Lyngbya* dominates the mid littoral.

(v) Hormosira banksii *Association.*—Throughout most of the inlet *Hormosira banksii* forms a conspicuous zone, varying in width from a few feet to 100 yd (see Fig. 1). On the western coast of the inlet, and between Strawbridge Point and Picnic Point, *Hormosira* is almost absent from long areas, occurring only on small rocky outcrops. The plants grow on rock or on the mollusc *Brachyodontes erosus* Lamarck embedded in the mud, and do not occur where the substratum is mud without *Brachyodontes*.

Hormosira forms a pure and dense association (Plate 4, Fig. 2; Plate 5, Fig. 2). On the lower side it merges with the sublittoral fringe association of *Hypnea-Spyridia*, but only scattered *Hormosira* plants occur in the latter association proper. *Ulva lactuca* Linnaeus (Plate 6, Fig. 1) and *Chaetomorpha billardieri* Kützing (Plate 5, Fig. 1) occur in the lowest part of the *Hormosira* association, and may become co-dominant, while in some places stunted tufts or fragments of *Corallina* are found.

The plants of *Hormosira* at American River inlet are much branched, to 25 cm long, and with individual vesicles up to 3½ cm in diameter. This is the forma *labillardieri*, and is very different in form from forma *sieberi* of rougher localities. Another difference is that *Hormosira* in the inlet is never epiphytized by *Notheia anomala* Bailey & Harvey, as it is on most rough coasts.

Hormosira can withstand the exposure to air, and to high temperatures in summer, because of its large water-containing vesicles. No other alga in the inlet is adapted to withstand lower littoral conditions so well.

Epiphytes on *Hormosira* are few. During winter months *Ectocarpus confervoides* is often densely epiphytic, while at most seasons a small *Lophosiphonia* (?) grows over the vesicles.

The mollusc *Austrocochlea zebra* Menke occurs on *Hormosira*, and a small anemone is found in sand near the base of rocks in the lower and even the mid littoral.

(vi) *Minor Communities of Sandy Areas.*—Two communities, both rather variable in their occurrence, are found on sandy areas of the lower littoral or just below. These are dominated by *Ectocarpus confervoides* (which occurs only in winter) and *Polysiphonia patersonis*. Both species may occur together, or quite separately, in areas around Samphire Island, between Strawbridge Point and Picnic Point, and elsewhere in the inlet. They are usually attached to cockle (*Katelysia scalarina* Lamarck) or other shells in the sand.

(c) *The Sublittoral Fringe*

(i) Hypnea musciformis-Spyridia biannulata *Association*.—This association of the sublittoral fringe occurs for about 1-1½ ft below the *Hormosira* association. It is characterized by a variety of species, with *Hypnea musciformis* and *Spyridia biannulata* usually dominant and *Centroceras clavulatum* (Agardh) Montagne a common constituent.

In a few places this association does not occur. North of the American River jetty *Zostera* extends shorewards to a fairly steeply shelving sand-pebble beach, and only scattered plants of *Hypnea* and *Spyridia* are found amongst the *Zostera*. Similar areas occur between American River jetty and Muston, and between Strawbridge Point and Picnic Point. Throughout the lagoons,* however, the *Hypnea-Spyridia* association is fairly distinct, although in many places this and the *Zostera* association grade over several yards.

The majority of algae in the sublittoral fringe are Rhodophyceae, with a few Chlorophyceae and Phaeophyceae. All the Rhodophyceae are yellow-brown in colour and are covered with a fine film of mud. They grow on cockle and other shells, or on small pebbles, buried in the mud.

The distinctive feature of the sublittoral fringe in the inlet is the dominance of Rhodophyceae and virtual absence of larger brown algae. This was stressed previously (Womersley 1947) and is referred to later in this paper.

Hypnea musciformis and *Spyridia biannulata* may each be dominant in some areas, but more often occur together. *Centroceras clavulatum* is rather variable, and less conspicuous, and has therefore been dropped from the name of the association as given previously (Womersley 1947). Numerous other species occur in the association, but are variable in occurrence and density. Some of them form almost pure localized communities in a few places. Notes on these species are given below. Unless otherwise stated they are restricted to the zone from about the 1·3 ft to the −0·5 ft levels, but some extend deeper while others (e.g. *Ulva*, *Chaetomorpha billardieri*) extend up into the lowest littoral zone. *Ulva lactuca* is often a very common constituent of the sublittoral fringe and extends into the *Hormosira* association (Plate 6, Fig. 1). In winter it may form (with *Enteromorpha clathrata*) a prominent green strip along the shore, often lying partly on the *Zostera* association. The plants reach a length and expanse of 50 cm or more (forma *latissima*). A common epiphyte is *Myrionema strangulans* Greville.

Enteromorpha clathrata is common and widespread throughout the inlet. Bliding's type II often forms a dense belt along the flats (with *Ulva*) where it is just exposed at low tide, while Bliding's type III (*E. plumosa* Kützing) is frequently found as dense masses in the sublittoral fringe.

Local communities of *Acetabularia peniculus* (R. Brown) Solms-Laubach and *Lithothamnion erubescens* Foslie (?) occur in the lagoons. The former grows on old cockle-shells, while the *Lithothamnion* forms unattached nodules (2-8 cm across) or crusts on exposed rock.

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* The term "lagoons" includes those parts of the inlet south of Muston.

The following species are scattered throughout the sublittoral fringe, varying considerably in abundance in different parts: *Cladophora fascicularis* (Mertens) Kützing, *Chaetomorpha billardieri* (extending down from the lower littoral), *Chaetomorpha valida* (Hooker & Harvey) Kützing, *Codium duthiae* Silva ined., *Caulerpa remotifolia* Sonder, *Caulerpa simpliciuscula* (Turner) C. Agardh var. *vesiculifera* Harvey, *Ectocarpus confervoides*, *Dictyota dichotoma* (Huds.) Lamouroux var. *intricata* (Agardh) Greville, *Stilopsis harveyana* Kylin, *Cystophora cephalornithos* (Labilladiere) J. Agardh, *Cystophyllum muricatum* (Turner) J. Agardh, *Sargassum biforme* Sonder (rare except where currents are strong), *Gelidium pusillum* (growing in coarse tufts), *Corallina* sp. (hemispherical masses to 15 cm across), *Jania natalensis* Harvey, *Gracilaria confervoides* (L.) Greville, *Centroceras clavulatum*, *Polysiphonia fuscescens* Harvey, *Polysiphonia patersonis*, *Chondria dasyphylla* (Woodward) C. Agardh, *Laurencia gracilis* Hooker & Harvey (?), *Laurencia majuscula* (Harvey) Lucas, and *Laurencia tasmanica* Hooker & Harvey.

Several animal groups are represented in the sublittoral fringe. Crustaceans occur in enormous numbers amongst the *Chaetomorpha* mats and other algae. *Brachyodontes erosus* is common, and a purple sponge (2-6 cm high) occurs just below the *Hormosira* zone in the lagoons. Other shells, polychaetes, etc. are common in the mud and under any small stones.

(ii) Lepilaena preissii *Association.*—The brackish-water angiosperm *Lepilaena preissii* (Lehm.) F. Muell. forms a pure and dense association in several isolated parts of the inlet (see Fig. 1). The reasons for its distribution are not clear, but it seems to prefer a muddy substratum between the 1·5 and 0·6 ft levels. Few algae occur with it.

(*d*) *The Sublittoral*

Associations which extend well below lowest tide level, as distinct from those limited just below this level, will be dealt with under the sublittoral zone.

(i) Zostera muelleri *Association.*—*Zostera muelleri* covers large areas of the tidal flats and forms a dense association (see Fig. 1). It occurs as an almost continuous band around the coast except for a few places on either side of Wallaby Point which are either rocky or sandy. Most luxuriant growth occurs between the 1·0 and —4 ft levels, but it may reach —8 ft and often extends into the lower littoral (though it is poorly developed here). Frequently it is mixed with the *Hypnea-Spyridia* association, and sublittoral fringe species such as *Gracilaria confervoides*, *Cystophora cephalornithos*, and *Cystophyllum muricatum* are found in the *Zostera* association in some places. In a few areas (see Fig. 1) *Zostera* occurs nearer the shore than *Hormosira*, owing to lower-lying areas between *Hormosira* and the shore.

Zostera is often free from epiphytes, but more usually has masses of *Cladophora* sp. or *Centroceras clavulatum* growing on the leaves. These masses of epiphytes float on the water surface at low tide if not growing in the deeper parts of the association. Other epiphytes on *Zostera* are *Rivularia polyotis* (Agardh) Bornet & Flahault, diatoms, and minute blue-green algae.

(ii) Posidonia australis *Association.*—*Posidonia australis* forms a dense association in all the deeper parts of the inlet, from the —0·5 ft level downwards. The long strap-like leaves just project above the surface at low tide in higher parts of the association, giving a very characteristic appearance (Plate 6, Fig. 2; Plate 7, Fig. 1).

On the south side of the channel between Muston and Wallaby Island are extensive beds of *Zostera*, growing in a depth of water in which *Posidonia* is normally dominant. Why *Zostera* is dominant here is not clear. Along most of the channel edge *Posidonia* forms a distinct band, from 1 to 50 yd wide.

Posidonia is remarkable for the wealth of epiphytes growing on the leaves. The commonest ones are: *Polysiphonia succulenta* Harvey, *P. mollis* Hooker & Harvey, *Jania micrarthrodia* Lamouroux (north side of Pelican Lagoon and just outside the inlet especially), *Crouania vestita* Harvey, *Asperococcus bullosus* Lamouroux (best developed in winter), *Colpomenia sinuosa* (Roth) Derbes & Solier, *Laurencia gracilis*, *Rivularia polyotis*, *Centroceras clavulatum*, and *Ceramium miniatum* Suhr. Other less common species are: *Polysiphonia davyae* Reinbold, *Ceramium* spp., *Griffithsia tenuis* Agardh, *Ulva lactuca*, *Enteromorpha clathrata*, *Cladophora fascicularis*, *Ectocarpus* spp., *Sphacelaria furcigera* Kützing, *Rivularia atra* Roth, *Calothrix confervicola* (Roth) Agardh, and *Microdictyon umbilicatum* (Velley) Zanardini.

The reason for this wealth of epiphytes lies in the rough fibrous leaves of *Posidonia*. The other marine angiosperms (*Zostera*, *Halophila*, *Lepilaena*) have much smoother leaves and bear far fewer epiphytes.

In shallower water near the shore *Posidonia* becomes less dense, and here other species may grow amongst it. Often the *Zostera* and *Posidonia* associations merge over several yards, while *Dictyota dichotoma* var. *intricata*, *Cystophyllum muricatum*, and *Cystophora cephalornithos* occur as scattered plants in some areas.

In Pelican Lagoon there are a number of deep holes (2½-3 fm) in shallower areas. These holes bear a dense growth of masses of *Caulerpa remotifolia* on the sides and bottom, while the edges are often muddy with little growth.

(iii) Halophila ovalis *Association.*—*Halophila ovalis* (R.Br.) Hook. f. grows as a fringe in deeper water along the channel, and as small patches in deeper water in the lagoons. On a bank 4-8 ft below mean low tide level, between the flats north of American River jetty and the channel proper, it is pure and dense. More frequently, however, it is mixed up with *Zostera* and *Posidonia*, and may extend as high as the zero tide level.

Epiphytes on *Halophila* are few. Occasionally *Ectocarpus confervoides* and *Ceramium* sp. grow on the leaves.

(iv) *The Flora of the Channel.*—The channel proper supports little algal growth owing to the loose, shelly bottom which must constantly shift with the strong tidal current. Near Muston, however, there are rocky parts in the channel on which grow *Sargassum biforme* (to 1½ m tall) and *Scaberia agardhii* Greville. On some larger shells small plants of *Laurencia forsteri* (Mert.) Greville occur, while just outside the mouth of the inlet *Chiracanthia arborea* (Harvey) Falkenberg and *Polysiphonia fuscescens* are plentiful in 2-3 fm.

Along the edge of the channel near Muston, and probably on rock in the channel, numerous species occur which are rarely found elsewhere in the inlet. Most of them are Rhodophyceae. Their presence is due to a relatively firm substratum in deeper water, together with the water movement of the tidal current. Many of the species are removed and cast up by boisterous conditions in late winter. They also grow on the deeper flats north of American River jetty, and occasionally along the channel elsewhere (rarely extending to the 0·0 ft level) but most of the drift material near American River jetty after storms seems to come from outside the inlet.

The species concerned are: *Caulerpa hypnoides* (R.Br.) Agardh, *Cutleria multifida* Greville, *Helminthora australis* J. Agardh, *Callophyllis ceratoclada* (J. Agardh) Womersley, *Botryocladia obovata* (Sonder) Kylin, *Champia obsoleta* Harvey, *C. affinis* (Hooker & Harvey) J. Agardh, *C. tasmanica* Harvey, *Lomentaria australis* (Kützing) Levring, *Griffithsia antarctica* Hooker & Harvey, *G. flabelliformis* Harvey, *G. ovalis* Harvey (rare), *Wrangelia protensa* Harvey, *Ceramium rubrum* (Huds.) C. Agardh, *Heterosiphonia gunniana* (Harvey) Falkenberg, *Halodictyon arachnoideum* Harvey, *Hypoglossum spathulatum* (Kützing) J. Agardh, *H. revolutum* (Harvey) J. Agardh, *Nitophyllum* sp., *Sarcomenia dolichocystidea* J. Agardh, *Polysiphonia cancellata* Harvey, *P. fuscescens*, *P. hookeri* Harvey, *P. roeana* Harvey, *Chiracanthia arborea*, *Brongniartella australis* (Agardh) Schmitz, *Lophocladia harveyi* (Kützing) Schmitz, *Coeloclonium opuntioides* (Harvey) J. Agardh, *Chondria dasyphylla*, *Dictymenia harveyana* Sonder, and *Jeannerettia pedicellata* (Harvey) Papenfuss.

Among the animal groups, sting-rays, eagle rays, and other smaller rays are common in the channel. Various kinds of sharks also occur, and starfish are often very plentiful on sandy patches on the edge of the channel. Large yellow sponges occur in the deeper parts of the channel.

(v) *The Flora of the Buoys.*—Two buoys near American River jetty and several outside the mouth of the inlet provide a habitat for some species which are not found elsewhere in the inlet. The rushing water movement around the buoys as the tide ebbs and flows, and the less murky water in the channel, provide conditions rather different from those on the tidal flats.

Common species on the buoys are: *Ulva lactuca*, *Enteromorpha clathrata*, *E. compressa* (L.) Greville, *Cladophora fascicularis*, *Bryopsis minor* Womersley, *Ectocarpus confervoides* (winter), *E. fasciculatus* (Griff.) Harvey, *Colpomenia sinuosa*, *Scytosiphon lomentarius* (Lyngbye) J. Agardh, *Bangia fuscopurpurea* (Dillwyn) Lyngbye (winter), *Acrochaetium* sp., *Gloiosaccion brownii* Harvey, *Champia obsoleta*, *Corynospora australis* Harvey, *Wrangelia plumosa* Harvey, *Dasya naccarioides* Harvey, *Polysiphonia abscissa* Hooker & Harvey, *P. succulenta*, *P. mollis*, *Chondria dasyphylla*, and *Laurencia forsteri*. Less common species are *Callymenia cribrosa* Harvey, *Gloioderma halymenioides* (Harvey) De Toni, and *G. fruticulosum.*

The buoys are cleaned each year, so fast-growing species are more prominent. In winter *Bangia fuscopurpurea* forms a band 1-2 in. high just above the water level, and *Enteromorpha* just at or below water level, while *Scytosiphon* and *Ectocarpus confervoides* are prominent below this. Most of the other species occur on the lower sides or underneath the buoys. During winter a fringe of *Ulothrix pseudoflacca* Wille grows at the water-line on boats which have not been cleaned, with *Enteromorpha* below it.

V. AMERICAN RIVER INLET AS A DISTINCT MARINE FORMATION

In the introductory account of the algal ecology of Kangaroo Island (Womersley 1947), reasons were advanced for regarding American River inlet as an algal formation distinct from the rest of the coast of the island. It is perhaps better referred to as a "marine" formation, as angiosperms and animals as well as algae are involved. Following the terminology of Cotton (1912) it was called the "sand and sandy-mud flat formation". The following are regarded as the distinctive features:

(1) The very calm environmental conditions, with wave action at a minimum. This has allowed the development of wide tidal flats of mud or sand, with occasional exposed rock in the littoral zone.

(2) The characteristic flora, of which the main features are the virtual absence of large brown algae in the sublittoral fringe, and the presence of very extensive beds of the marine angiosperms, *Zostera* and *Posidonia*.

The detailed survey of the inlet that has now been made has substantiated the opinions previously expressed, but has shown that there are a few exceptions within the inlet.

The absence of large brown algae (*Cystophora*, *Sargassum*, etc.) in the sublittoral fringe within the inlet is not complete. For instance, *Cystophora polycystidea* dominates the sublittoral fringe over some 300 yd of the north coast of Pelican Lagoon. This alga is a characteristic component of the upper sublittoral on parts of the north coast of Kangaroo Island. The reasons for its occurrence in the inlet are the sharp drop of the cliffs to 3 or 4 ft below low tide level, and a greater degree of wave action due to the prevailing south-west winds passing over some 2 miles of open water, coupled with deeper water close inshore.

This small area of coast is a fragment of the sheltered rocky coast subformation within the inlet, owing to the unusual conditions.

Three other species of larger brown algae occur within the inlet, viz. *Cystophora cephalornithos*, *Cystophyllum muricatum*, and *Sargassum biforme*. These species, however, are never found dominant in the sublittoral fringe, and in general are not common. *Sargassum biforme* is restricted to the channel where water movement is greater, while the *Cystophora* and *Cystophyllum* occur in some areas as scattered plants in the sublittoral fringe and just below. The latter are two of the few species of fucoids which grow well under very calm conditions and where the temperature range is considerable. *Cystophyllum muricatum* also occurs on the much rougher south coast reefs (though as a stunted form), but *Cystophora cephalornithos* is rare outside the inlet.

The development of beds of *Zostera* is restricted to American River inlet (or similar very calm bays) and this seems to be a useful distinguishing characteristic. *Posidonia* beds, however, occur elsewhere around Kangaroo Island, but always in deeper water. The *Posidonia* at the inlet is a broad-leaved form, whereas elsewhere it is mostly a narrow-leaved form (probably a distinct species).

Many other differences between American River inlet and the rest of Kangaroo Island coast are found. Species characteristic of the south coast are rarely found in the inlet, and vice versa, although some species with wide environmental tolerance occur in both calm and rough localities. In species such as *Hormosira banksii*, distinct ecological forms are largely restricted to the different formations.

Animals also provide points of difference. Barnacles (*Elminius*) are virtually absent from the inlet (except where wave splash is greater, or on jetty piles), whereas they form a conspicuous feature of the upper littoral on the rest of the north coast. Characteristic molluscs of the north coast such as *Melaraphe unifasciata* Gray, *Melanerita melanotragus* Smith, *Cellana tramoserica* Sowerby, and *Siphonaria diemensis* Sowerby are also absent from the inlet but for a very few restricted places.

American River inlet, if considered as a whole, presents many features of its marine ecology which justify its being considered as a distinct marine area. Following Cotton (1912) and others, it can well be termed a "sand and sandy-mud flat formation". The merits of this use of "formation", as against the application by Feldmann (1951) and others of this term to a grouping of associations of similar life form, will not be discussed further here.

Few similar areas of the Australian coastline have been studied from the ecological viewpoint. Guiler (1951) describes Pipe Clay Lagoon, near Hobart in Tasmania. This lagoon shows similarities to American River inlet in the *Arthrocnemum-Salicornia*, *Bembicium melanostoma*, and *Zostera* associations, but differs in the absence of *Posidonia* and apparent lack of many algal species.

Several areas of the South Australian coastline are similar to American River inlet, viz.: on the west coast of Eyre Peninsula, parts of Denial and Smoky Bays, Beard's Bay, Venus Bay, and parts of Coffin Bay; in the gulf region, Proper Bay near Port Lincoln, Franklin Harbour, and many small bays or sheltered areas within Spencer's Gulf and St. Vincent's Gulf. Wherever very calm, sheltered conditions occur, with sandy or muddy tidal flats, the American River inlet ecosystem probably occurs. Apart from the South Australian coasts, such sheltered bays or inlets are less frequent, but parts of King George's Sound in Western Australia, Port Phillip in Victoria, and areas such as Pipe Clay Lagoon in Tasmania may show similarities. Although good accounts are available of exposed parts of the New South Wales coastline (Dakin, Bennett, and Pope 1948), ecological studies on calm areas are lacking.

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Explanation of Plates 1-7

Plate 1

Fig. 1.—View over American River inlet at high tide from the south, looking slightly east of north. Pelican Lagoon is on the far right, American River settlement on the upper left, and the head of the inlet in the right foreground.

Fig. 2.—Tidal flats backed by samphires, below which appear: (1) a light-coloured zone of *Bembicium*; (2) a darker grey zone of *Hormosira*; (3) the sublittoral fringe just covered by water, with the edge of a *Posidonia* bed just exposed on the right.

Plate 2

Fig. 1.—The samphire association of the supralittoral. The larger bushes are *Arthrocnemum arbuscula*, the lower ones *Salicornia australis*.

Fig. 2.—The coast near Salt Lake Point, showing the low cliffs (8-12 ft high) with small shaded caverns and hollows at the base, backing the gently sloping mud flat.

Plate 3

Fig. 1.—*Bostrychia simpliciuscula* on rocks withdrawn from a shaded hollow of the upper littoral.

Fig. 2.—*Gelidium pusillum* as a dark mat on rock in a part relatively exposed to waves—hence the lower zone of serpulid worm tubes, various limpets (*Siphonaria*), and *Melanerita* which are not characteristic of most of American River inlet.

Plate 4

Fig. 1.—*Bembicium melanostoma* on firm mud in the mid littoral.

Fig. 2.—General view of the *Hormosira* association of the lower littoral, exposed during low tide.

MARINE ALGAE OF KANGAROO ISLAND. IV

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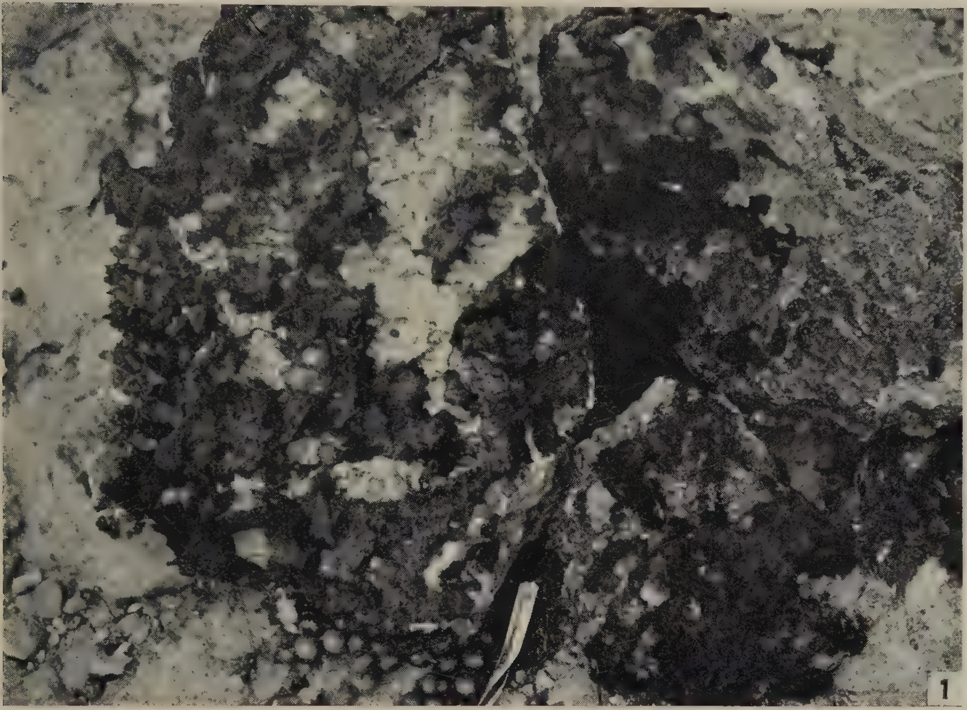
2

MARINE ALGAE OF KANGAROO ISLAND. IV

1

2

MARINE ALGAE OF KANGAROO ISLAND. IV



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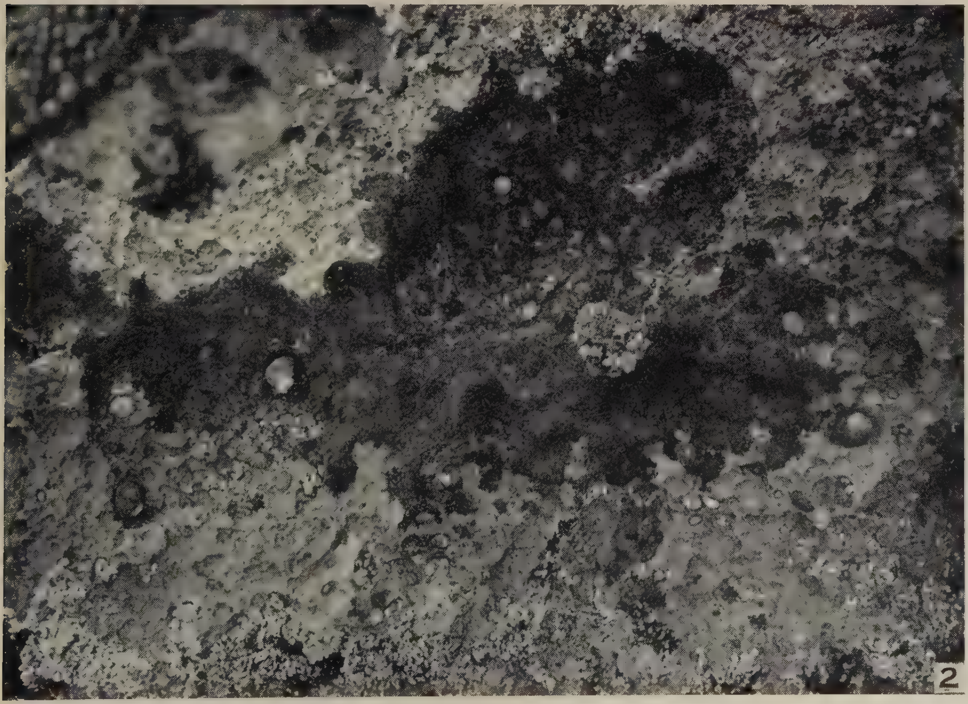

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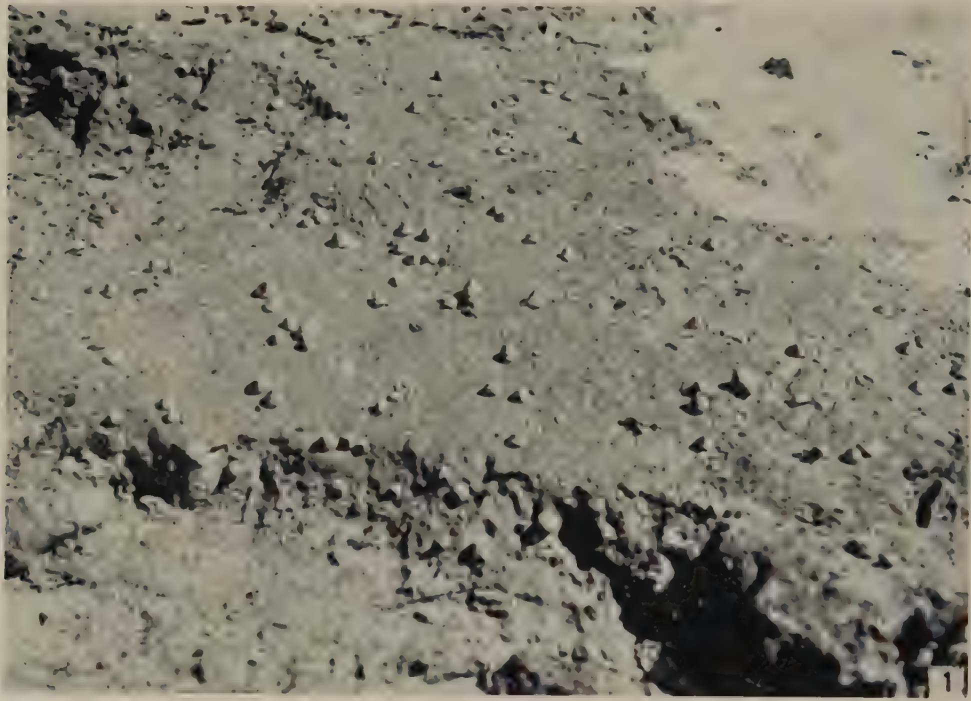
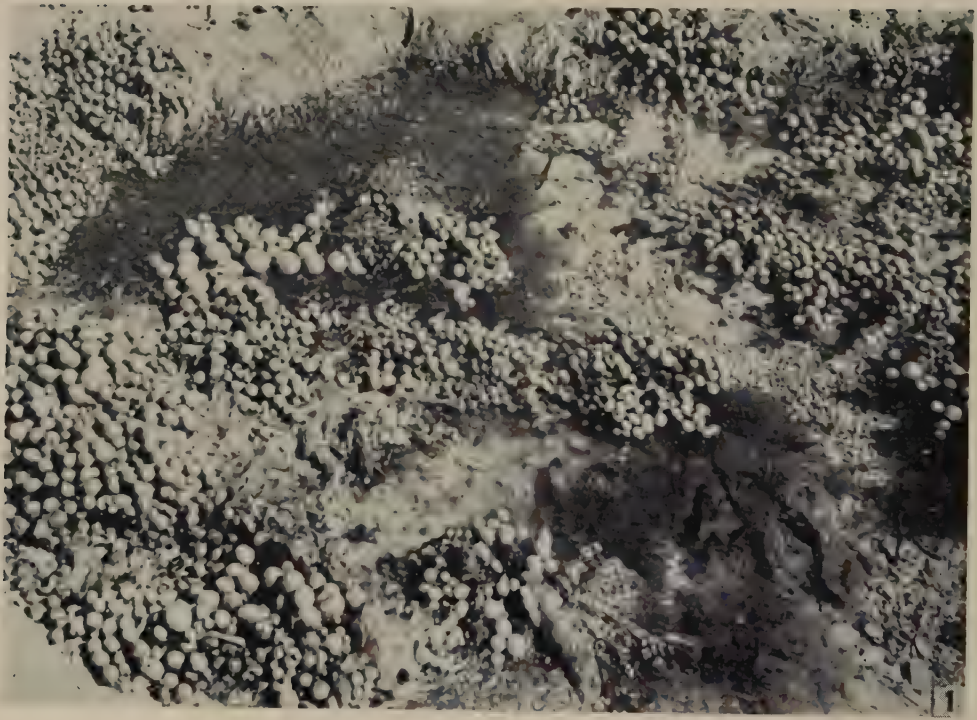


MARINE ALGAE OF KANGAROO ISLAND. IV

1

2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2

MARINE ALGAE OF KANGAROO ISLAND. IV

Plate 5

Fig. 1.—*Hormosira banksii*, with part of an extensive mat of *Chaetomorpha billardieri* on the left.

Fig. 2.—A dense and pure area of *Hormosira banksii* in the lower littoral. The largest bladder is about 2½ cm across, with prominent conceptacles.

Plate 6

Fig. 1.—Lower parts of the *Hormosira* association, with *Ulva lactuca* in shallow water-retaining depressions or just exposed.

Fig. 2.—A *Posidonia* bed at low tide, with the leaves just projecting above the water surface, and patches of epiphytes floating on the surface.

Plate 7

Fig. 1.—The edge of a *Posidonia* bed, with various algae of the sublittoral fringe (*Hypnea*, *Laurencia*, *Asperococcus*) in the foreground.

THE ECOLOGY AND DISTRIBUTION OF INTERTIDAL ORGANISMS ON THE ROCKY SHORES OF THE QUEENSLAND MAINLAND

By R. Endean,* R. Kenny,* and W. Stephenson*

[*Manuscript received August* 17, 1955]

Summary

This paper records investigations made on the ecology and biogeography of organisms found on rocky shores in eastern Queensland.

Traverses were made at selected localities along a region of the coast bounded by the New South Wales-Queensland border (lat. 28° 15′ S.) to the south and Whitecliffs (lat. 16° 39′ S.) to the north. An account of general physiographic features and environmental factors in this region is given.

It was found that the majority of typical Peronian organisms extended as far north as about lat. 25° S. North of lat. 25° S. tropical species occurred and the degree of overlapping of species from the two adjacent faunas was very small. However, the Moreton Bay-Caloundra region offered a refuge for some tropical forms.

Zonation patterns on either side of the biogeographical boundary differed. In southern Queensland the zonation picture was similar to that in New South Wales as described by Dakin, Bennett, and Pope (1948); but in northern Queensland an oyster zone dominated the upper half of the intertidal region, whilst in the lower half a barnacle zone replaced the serpulid zone found in southern Queensland and New South Wales.

The effects of various environmental factors on zonation on Queensland shores are discussed. It has been found that generalizations made by Evans (1947*b*) regarding zonation on British shores are only partially applicable to zonation in southern Queensland. Possible reasons for the differences noted are discussed. Also, the rate of change of percentage exposure to the air, which Doty (1946) has shown to be so potent a factor in determining the zonation of organisms at all levels in the intertidal region of the coasts of Oregon and northern California, apparently determines only the upper levels attained by organisms which extend above mean high water neap tide level on southern Queensland shores.

Analyses of the effects of varying environmental factors, including gross environmental changes relating to latitude, on faunistic composition have been made. These have given much information on the general ecology of many common Queensland rocky shore species. Moreover, they have thrown much light on the reasons for the existence of a biogeographical boundary near latitude 25° S. In particular they have shown that such factors as the degree of wave action and salinity are possibly of more importance than temperature in determining the position of this boundary.

I. Introduction

Despite the existence of a considerable faunistic and taxonomic literature on the marine invertebrates of Queensland (see Dall and Stephenson 1953), relatively few ecological studies have been made over this extensive sector of the Australian coast. Of these studies, the most intensive are concerned with coral habitats (Mayer 1918; Hedley 1925*a*; Rainford 1925; Stephenson *et al.* 1931; Manton and Stephenson

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1935). Consequently such studies cannot be compared readily with work carried out in other parts of Australia, which has been concerned largely with the ecology of intertidal rocks (Hedley 1915; Ward 1937; Fischer 1940; Pope 1943; Dakin, Bennett, and Pope 1948; Edmonds 1948; Guiler 1950, 1951*a*, 1951*b*, 1952*a*, 1952*b*, 1952*c*; Womersley and Edmonds 1952; Bennett and Pope 1953).

Apart from brief mentions by Guiler (1952*c*) and by Bennett and Pope (1953), the only published works dealing specifically with this habitat on the Queensland mainland are those of Tenison-Woods (1881), which refers to some littoral species found near Port Douglas, and Johnston (1917) on the ecology of Caloundra, about 40 miles north of Brisbane. Johnston gave an account of the chief organisms and the general zonation. He concluded that the same zones were present as in New South Wales but the dominant organisms differed and in some groups there was a high proportion of tropical forms. This was also commented on by Bennett and Pope (1953). However, as is shown in this paper, the intertidal picture at Caloundra is atypical of that occurring in southern Queensland generally.

Guiler (1952*c*, p. 48) stated that the "Queensland coasts can be divided into the coral reef areas and the semi-tropical areas of southern Queensland. The latter may have a zoanthid fauna . . .". He also referred to an oyster zone, stating that the oysters, *Ostrea mordax* Gould (= *Crassostrea amasa*), are found on semi-exposed and sheltered coasts and that "below the oyster band is a thin strip of large barnacles and oysters, e.g. on West Molle Island and this is followed by a bare belt which often has a deposit of mud and silt on it". He also stated that the lowest part of the mid littoral is occupied by alcyonarians which are followed by hard corals. Guiler's picture is entirely misleading and is based presumably on a very few atypical localities.

The present work was undertaken with the following main objectives:

(1) To ascertain the common organisms on intertidal rocks in eastern Queensland.

(2) To obtain information on their general ecology.

(3) To investigate the basic zonation of the dominant forms at selected localities.

(4) To determine the effect of latitude and other variables on faunistic composition and zonation. It might be expected, for example, that owing to the proximity of the Great Barrier Reef to the mainland in central and northern Queensland a coral zone would be present, replacing the algal zone of the traditional zonation picture as outlined by Stephenson and Stephenson (1949).

(5) To re-examine the boundary between the Solanderian and Peronian provinces which has been placed at Wide Bay, about 26° S. (Hedley 1926; Clark 1946), and to ascertain as far as possible why such a zoogeographical boundary should exist.

In this study investigations were restricted to mainland localities. However, Curtis and Facing Islands and the islands enclosing Moreton Bay have long seaward coastlines and as they are separated only by shallow water from the mainland, they are here regarded as mainland localities. A subsequent paper will deal with some of the islands off the Queensland coast.

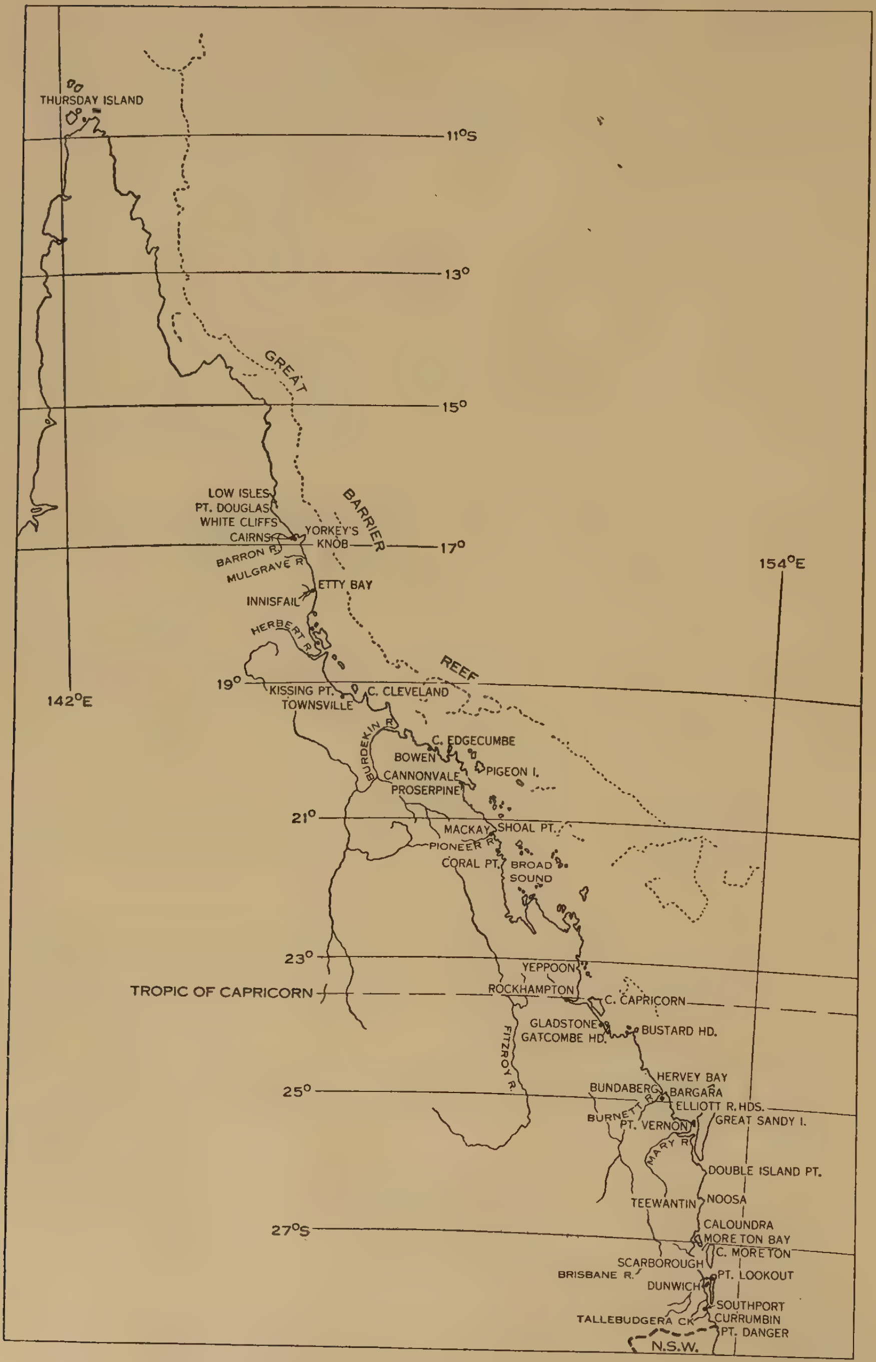
THURSDAY ISLAND
11°S
13°
GREAT
15°
LOW ISLES
PT. DOUGLAS
WHITE CLIFFS
CAIRNS
YORKEY'S KNOB
BARRIER
17°
BARRON R.
MULGRAVE R.
ETTY BAY
INNISFAIL
HERBERT R.
154°E
REEF
19°
KISSING PT.
C. CLEVELAND
TOWNSVILLE
142°E
BURDEKIN R.
C. EDGECUMBE
BOWEN
PIGEON I.
CANNONVALE
PROSERPINE
21°
MACKAY
SHOAL PT.
PIONEER R.
CORAL PT.
BROAD SOUND
23°
YEPPOON
TROPIC OF CAPRICORN
ROCKHAMPTON
C. CAPRICORN
GLADSTONE
GATCOMBE HD.
BUSTARD HD.
FITZROY R.
HERVEY BAY
BUNDABERG
BARGARA
25°
ELLIOTT R. HDS.
BURNETT R.
PT. VERNON
GREAT SANDY I.
MARY R.
DOUBLE ISLAND PT.
TEEWANTIN
NOOSA
CALOUNDRA
27°S
MORETON BAY
C. MORETON
SCARBOROUGH
BRISBANE R.
PT. LOOKOUT
DUNWICH
SOUTHPORT
TALLEBUDGERA CK
CURRUMBIN
PT. DANGER
N.S.W.

Fig. 1.—Map of Queensland showing localities and rivers mentioned in text.

II. Sites of Investigation

The sites of investigation are indicated in Figure 1. The area covered embraced over a thousand miles of coastline between the Queensland-New South Wales border (lat. 28° 10′ S., long. 153° 33′ E.) and Whitecliffs (lat. 16° 39′ S., long. 145° 34′ E.). Localities further south have been investigated by Dakin, Bennett, and Pope (1948); whilst further north, distances from Brisbane become excessive and the coastline is mostly inaccessible except by sea.

At the nearer and more accessible localities (Currumbin, Dunwich, Scarborough, Point Lookout, Caloundra, and Noosa) all three of the present authors were involved in repeated visits. The intermediate localities of Double Island Point, Point Vernon, Elliott River heads, and Bargara were visited once in the winter of 1952 by two of us (R.K., R.E.) and once in the following summer by all three of us. Yeppoon was also visited on the latter occasion. Only one visit by the three authors, during August 1953, has been made to the following localities, which are north of Yeppoon: Coral Point, Shoal Point, Cannonvale, Pigeon Island, Cape Edgecumbe, Kissing Point, Etty Bay, Yorkey's Knob, and Whitecliffs. Cape Moreton, Bustard Heads, Gatcombe Heads, Cape Capricorn, and Cape Cleveland were visited once (W.S.) in May 1954. As far as possible, visits to localities were made to coincide with the periods of spring tides.

Notes on the traverses made at each locality will be found in Appendix I.

III. General Account of the Queensland Coast

From the New South Wales-Queensland border to Great Sandy Island (about lat. 25° S.) the coastline runs predominantly northward, but north of this region it turns abruptly to the north-west and runs thus to Cape York.

The coastline of southern Queensland, which can be arbitrarily defined as being south of lat. 25° S., is characterized by a succession of rocky-cliffed headlands separated by long sweeps of sandy beach. Waves having their genesis in the South Pacific roll in on this coastline (Plate 1, Fig. 1; Plate 3, Fig. 2) except where it is protected by the islands which almost enclose Moreton Bay and Hervey Bay respectively. Very heavy seas occasionally pound this stretch of coast but the surf is not so consistently rough as it is in New South Wales.

Much of the coast north of about lat. 25° S. is "drowned". Evidence for this submergence can be found in the numerous coastal embayments which are only partially filled with alluvium and in the many hills and mountains which plunge steeply into the sea (see Steers 1929). The coastline of this region, which is hereafter referred to as the northern Queensland coast, usually presents a series of long sweeping arcs, each terminating to the south in a bay which is sheltered by a northerly directed rocky headland. Apparently the coastal contours have been influenced greatly by the existence of several north-west to north-north-west fault-lines, and in general it would appear that the geological "grain" of the country is to the north-north-west (David 1911; Bryan 1925; Richards 1928).

Also, in the region north of lat. 25° S. a number of archipelagoes are found. Their configuration, disposition, and geological structure suggests that most are drowned mountains now forming "continental islands" (see Steers 1929).

Commencing just south of lat. 7° S. and extending to about lat. 24° 30′ S. the reefs of the Great Barrier Reef follow the contours of the continental shelf. Thus the outer edge of the Great Barrier Reef is only about 10 miles from the mainland near Cape Melville (lat. 14° 10′ S.), but diverges from the coastline both north and south of this point. The reefs are furthest from the mainland near their southerly end, the easterly reefs of the Swain Group (about lat. 21° 0′ S., and long. 152° 41′ E.) being nearly 200 miles away. Between the outer reefs of the Great Barrier Reef and the mainland there is a channel or "lagoon" of variable width and here too are found platform reefs, shingle, and sand cays.

The coastline of northern Queensland is therefore protected from oceanic swell and the battering surf by the presence of innumerable reefs and islands. As a result, wave action on this coastline is much reduced and at many localities is almost negligible (Plate 5, Figs. 1 and 2; Plate 6, Fig. 1). However, some of the projecting headlands bear the brunt of waves generated in the "lagoon" by the south-east trades. Even so, wave action is never excessive and this is reflected in the fact that there are surprisingly few wave-cut cliffs in northern Queensland. Thus at Whitecliffs, for example, the rock face plunges straight into the water without any indication of benching. Furthermore, at many localities, e.g. Bargara, Cannonvale, and Cape Edgecumbe, the presence of small piled rocks and boulders in the intertidal region indicates a lack of wave action of any magnitude.

Clean sandy beaches are much rarer in northern Queensland than they are in southern Queensland and New South Wales. On the other hand mangrove flats occasionally fringe the shore, particularly in more sheltered localities adjacent to mouths of streams. The coastal rivers and streams deposit their sediment in the lagoon between the outer Great Barrier Reef and the mainland. Consequently the water near the mainland is usually turbid. Only the Burdekin River has formed a delta.

IV. Physico-chemical Factors

(a) *Sea Temperatures*

Data on sea temperatures along the Queensland coast were obtained principally from charts issued by the Royal Netherlands Meteorological Institute (1949) and are summarized in Figure 2. It is probable that these temperatures do not correspond with the temperatures of the water in the immediate vicinity of the localities investigated, particularly as some of these are situated in shallow, partially land-locked bays (e.g. Cannonvale). However, in southern Queensland a few recordings of sea temperature adjacent to rocks where traverses were made were well within the range expected for the particular time of the year from study of the charts. If the Moreton Bay data be excluded, it can be seen that the sea temperature along the Queensland coast varies fairly uniformly with latitude and that there are no regions on the coast where markedly colder or warmer bodies of water intrude. Indeed between the sea temperatures at the northernmost and southernmost localities visited, which are about 1200 miles apart, there exists a difference of only approx. 4° C in the annual mean minimum, and only approx. 3° C in the annual mean maximum.

Annual mean maximum and minimum water temperatures for Moreton Bay over the period 1928-1935 were abstracted from Crohamhurst Observatory Paper No. 3 (Crohamhurst Observatory 1936) and are of particular interest. They show a mean maximum of approximately 27·5° C and a mean minimum of approximately 14·5°. Thus the water in Moreton Bay has a mean summer maximum temperature approximately 2·5° warmer, and a mean winter minimum approximately 4·5° colder, than the oceanic water on the easterly side of the islands enclosing Moreton Bay.

(*b*) *Air Temperatures*

Air temperature data for Queensland coastal towns, based on records kept for 20 years or longer, were obtained from the Brisbane office of the Commonwealth Meteorological Bureau and are summarized in Figure 2. Analysis of the data revealed that the annual mean maximum and minimum temperatures for Cairns in the north are only 3° C higher than those for Southport in southern Queensland.

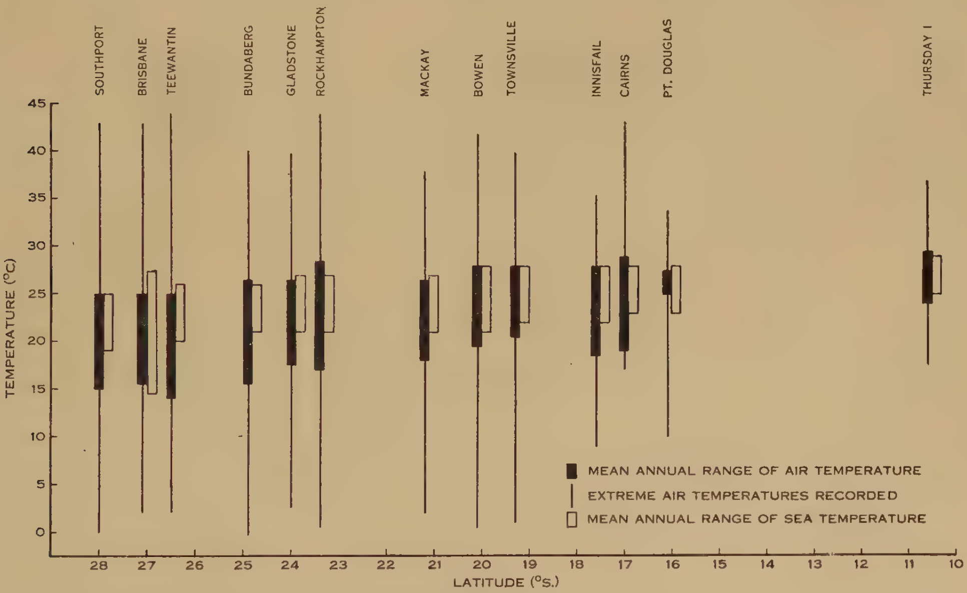

Fig. 2.—Air and sea temperatures at selected localities on the Queensland coast. Data obtained from the Brisbane office of the Commonwealth Meteorological Bureau and from publications of the Royal Netherlands Meteorological Institute.

(*c*) *Tides*

Figure 3 depicts tidal ranges (plotted to a common mean sea-level) for selected Queensland localities, using data abstracted from the Admiralty tide and tidal stream tables for 1953 (British Admiralty 1952). Between latitudes 20° and 24° S. the tidal range is much greater than at localities further to the north or south. It is probable that this increase in tidal amplitude is due to the shoreline conformation. According to the "Australia Pilot" (British Admiralty 1950), there is a tendency for the flood tidal stream to converge towards Broad Sound and for the ebb tidal stream to radiate from it.

(*d*) *Rainfall and Salinity*

There is little information available on the salinity of the water near the Queensland coast. Orr (1933) determined salinities in the vicinity of Low Isles. At a point 3 miles east of Low Isles the salinity ranged from 31·32‰ to 35·47‰ in 1929, lower salinities being found during the period of summer rainfall. Orr pointed out that during winter months "there is considerable disturbance of the sea and the water is kept well mixed from top to bottom during this period".

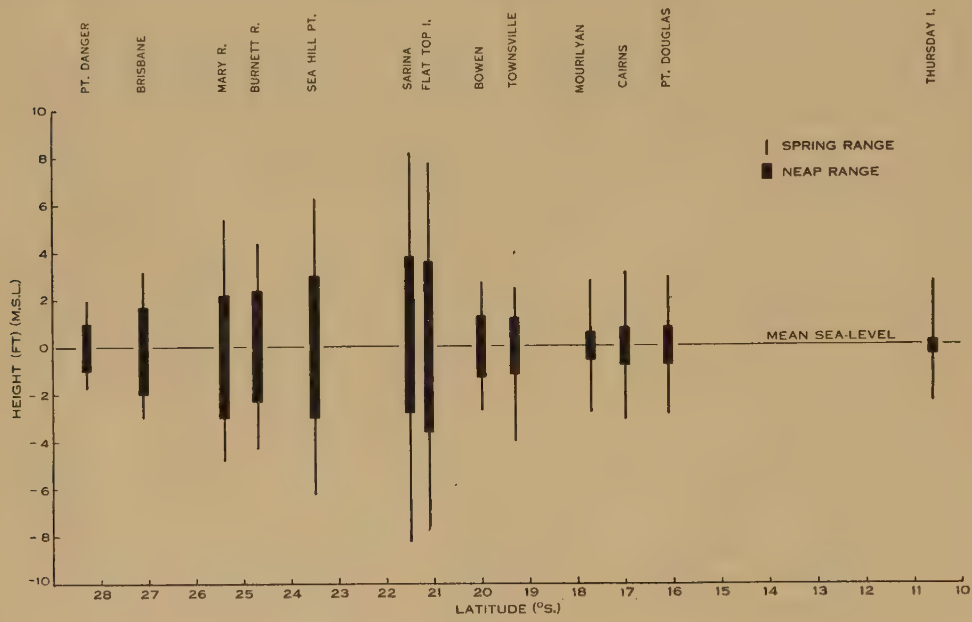

Fig. 3.—Tidal data for selected Queensland localities drawn to a common mean sea-level; data abstracted from Admiralty tide and tidal stream tables (British Admiralty 1952).

Figure 4*A* shows the annual rainfall at selected localities along the Queensland coast. Data were obtained from the Brisbane office of the Commonwealth Meteorological Bureau, and analysis showed that the major part of the rainfall is concentrated over the summer months. In addition there are long periods of calm weather inside the lagoon during summer and consequently less mixing. This would suggest that surface salinities there are lowest during summer. Towards the southern end of the Great Barrier Reef and in southern Queensland where the coast is exposed to oceanic swell, it is considered that surface salinities would not be greatly affected during this season.

In view of the foregoing, it is of interest to examine the outflow of some of the larger Queensland rivers. The data of Figure 4*B* were obtained from the Queensland Department of Irrigation and Water Supply. This graph indicates that the volume of fresh water carried into the lagoon by the Burdekin and Fitzroy Rivers, in particular, may be sufficient to have a considerable depressant effect on the salinity of the water near their mouths. Of the localities visited the ones most likely to be affected by this factor would be Yeppoon and Cape Capricorn, because of their proximity to the mouth of the Fitzroy River and to Point Vernon, which is near the mouth of the Mary River.

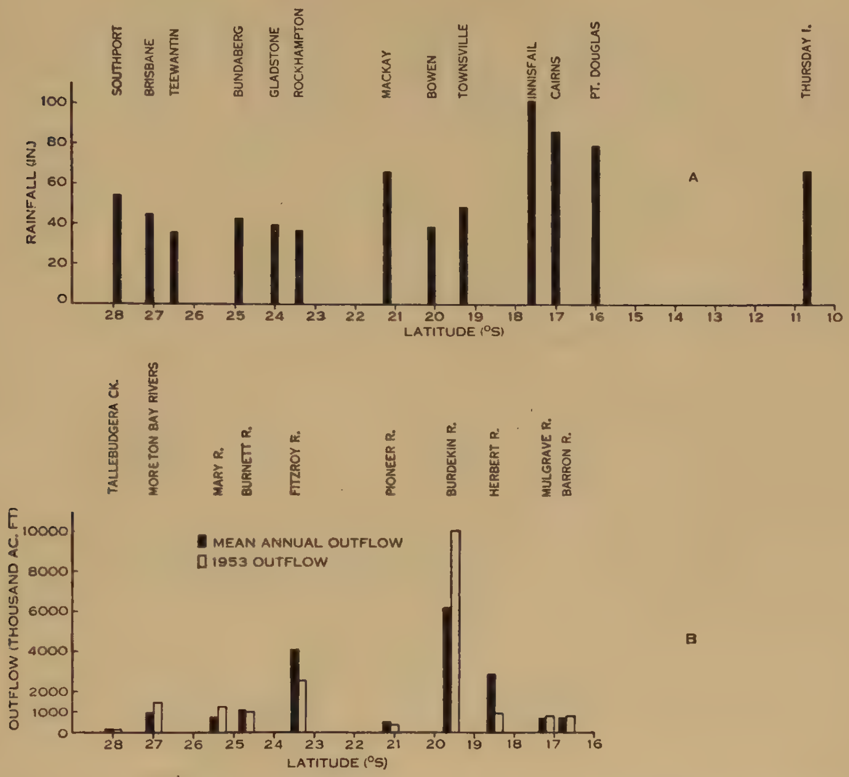

Fig. 4.—*A*, annual rainfall for selected Queensland coastal localities; data from the Brisbane office of the Commonwealth Meteorological Bureau. *B*, outflow from some Queensland rivers; data from Irrigation and Water Supply Commission (1954).

(*e*) *Turbidity*

A high degree of turbidity characterizes the water near the mainland and also that in the lagoon between the Great Barrier Reef and the mainland.

Hedley (1925*b*), using a modified Secchi disc, found that the disc vanished at a depth of 6 ft at the jetty at Townsville and at a depth of 8 ft at the jetty at Cairns. In the lagoon between the Great Barrier Reef and the mainland he found a minimum of 17 ft and a maximum of 109 ft.

At a station 3 miles east of Low Isles, Orr (1933) found that the average transparency over a period of 1 year was about 12 m, with a maximum of 22·5 and a minimum of 4·5 m. He attributed this turbidity primarily to winds causing sufficient turbulence in the shallow waters of the lagoon to stir up clay and fine silt. Nearer the Great Barrier Reef the water is much cleaner as the sea bottom is composed principally of coral and coral debris.

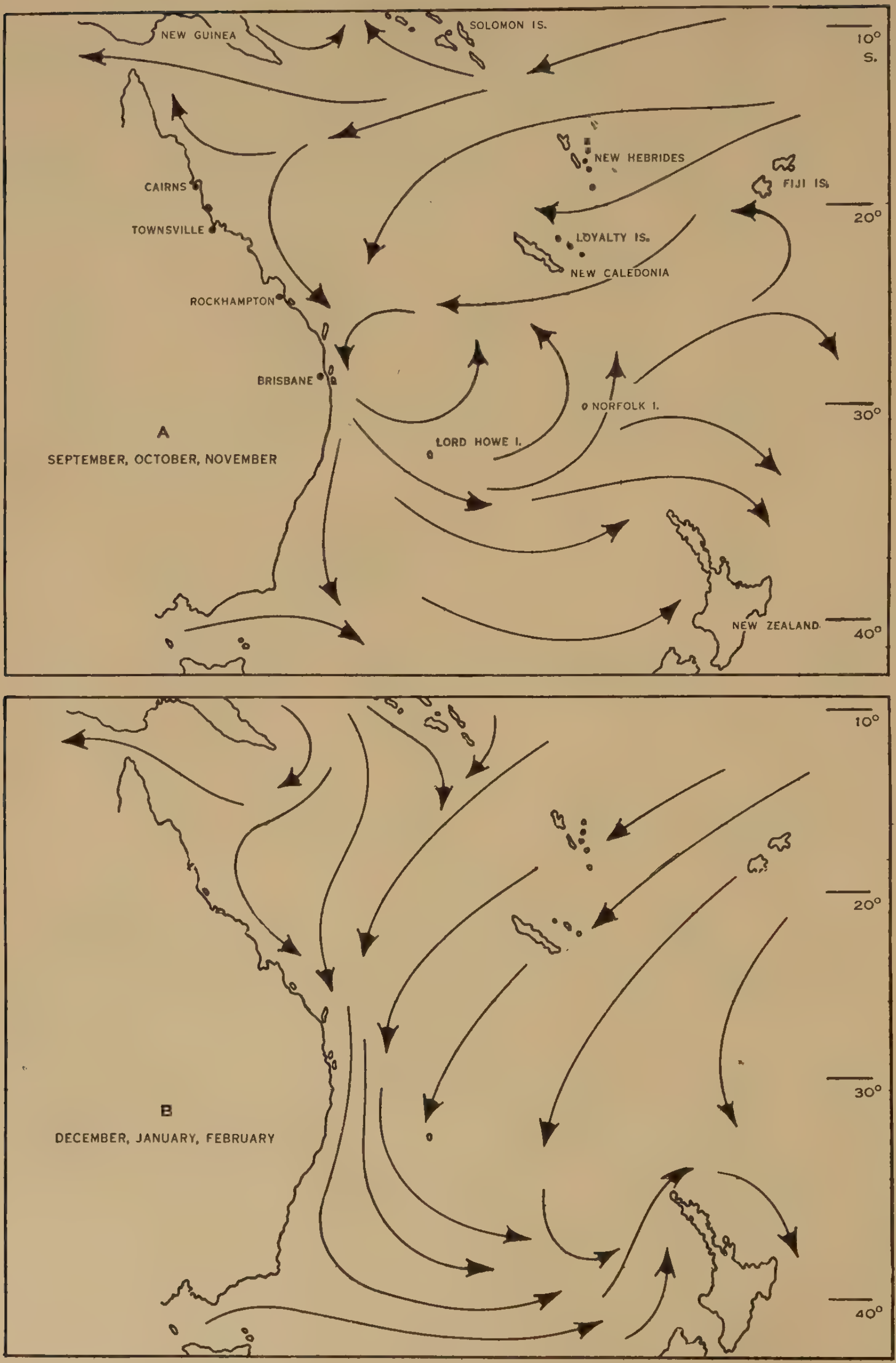
NEW GUINEA
SOLOMON IS.
10° S.
NEW HEBRIDES
FIJI IS.
CAIRNS
TOWNSVILLE
20°
LOYALTY IS.
NEW CALEDONIA
ROCKHAMPTON
BRISBANE
NORFOLK I.
30°
A
SEPTEMBER, OCTOBER, NOVEMBER
LORD HOWE I.
NEW ZEALAND
40°
10°
20°
30°
B
DECEMBER, JANUARY, FEBRUARY
40°

Fig. 5*A*-*B*.—Seasonal current charts for the Pacific Ocean region off the eastern Australian coast; data from publications of the United States Navy Hydrographic Office.

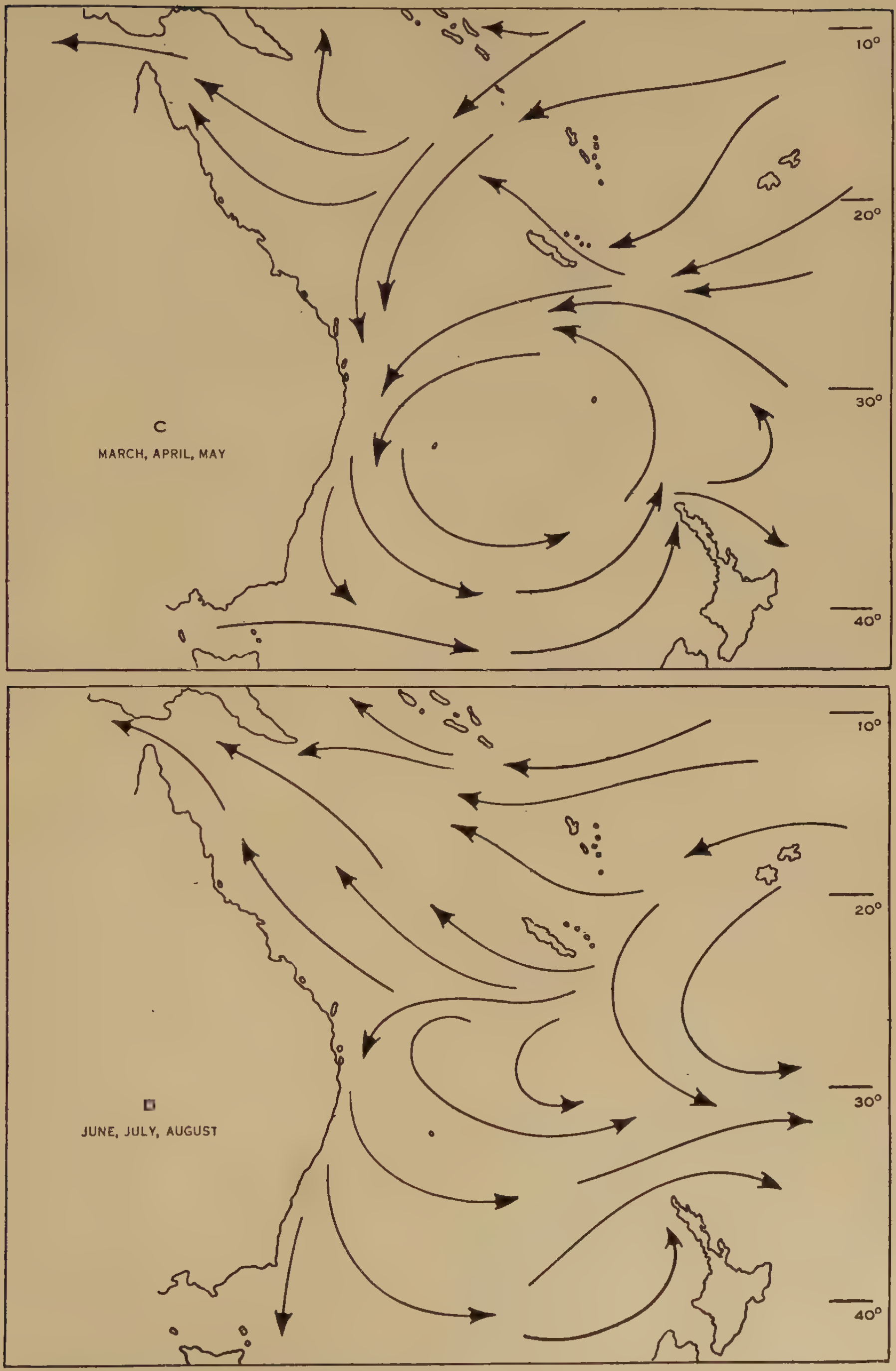
C
MARCH, APRIL, MAY
10°
20°
30°
40°
D
JUNE, JULY, AUGUST
10°
20°
30°
40°

Fig. 5*C-D*.—Seasonal current charts for the Pacific Ocean region off the eastern Australian coast; data from publications of the United States Navy Hydrographic Office.

The coastal rivers are responsible for carrying down large quantities of silt, especially after the summer rains. When these larger rivers are in flood, which is almost an annual event, discoloured water can be seen from the air to radiate out for many miles from the river mouths (see Fairbridge and Teichert 1947, 1948).

(*f*) *Winds*

The prevailing winds along the eastern Queensland coast are the south-east trades. Data on winds gathered over a period of 5 years were obtained for most of the Queensland coastal towns from the Brisbane office of the Commonwealth Meteorological Bureau. Analysis of this data showed that south-east winds blew from February-March to October-November. In the intervening periods winds were variable but mainly north-easterly. Further information on winds off the Queensland coast can be found in the charts showing wind roses issued by the Royal Netherlands Meteorological Institute in 1949, and in the tables of meteorological data for Low Isles gathered by the Great Barrier Reef Expedition (Orr 1933).

Waves are generated within the lagoon principally by the south-easterly winds, and consequently it is the south-easterly side of headlands and promontories that are most exposed to wave action.

Cyclonic disturbances often occur in late summer and early autumn. These originate often in the Coral Sea but their subsequent course is variable although frequently the disturbance travels in a south-westerly direction. Such disturbances are responsible for very rough seas for long distances along the Queensland coast. Even within the lagoon considerable seas are generated.

(*g*) *Currents*

A branch of the Pacific south equatorial current swings to the south of the Solomon Islands and bathes the shores of the New Hebrides and New Caledonia. It impinges on the Queensland coast in the vicinity of Great Sandy Island and then veers to the south, passing along the New South Wales coast as a broad current, well known to shipping (see Halligan 1921). The current is a warm one and its influence is reflected in charts showing sea isotherms off the eastern Australian coast, such as those issued by the Royal Netherlands Meteorological Institute (1949) to which reference has already been made.

According to the "Australia Pilot", Vol. III (British Admiralty 1950), the current south of lat. 25° S. occupies a belt from about 20 to 50 or 60 miles from the land, its greatest strength being found near the 100 fm line, the position of which varies between 10 and 30 miles offshore. However, there are frequent alterations both in strength and direction, especially seasonally. Sometimes there are reverse sets in a northerly direction. Also, close inshore there are frequently eddies setting northwards, notably along the coast to the north of Cape Moreton.

Figure 5 shows seasonal variation in the current circulation off the eastern Australian coast, excluding the region between the Great Barrier Reef and the mainland. In the latter region, the south-east trades are responsible for a northerly current from April to November. During the summer months when the south-east winds wane this current may be reversed (see "Australia Pilot", Vol. IV (British

Admiralty 1939)). However, the position within reef waters is complicated by the occurrence of strong tidal currents. In the region south of about lat. 18° S. the flood tide sets mainly to the south and the ebb to the north.

V. Methods

Most rocky shores provide a large number of intergrading habitats, with associated faunas of varying degrees of complexity. In particular, the "under stone" habitat has an embarrassingly large number of faunistic elements. In an attempt to reduce the present work to manageable proportions, only open exposed faces of rock and crevices were considered in detail. Decisions in the field as to the inclusion or exclusion of marginal types of niches were rarely difficult. For example, organisms deep in crevices and visible only after use of crowbars were normally excluded. Thus *Ibla cumingii* and *Perna nucleus*, which are crevice dwellers yet readily discernible, were included, whilst nereids and sipunculids situated deep in the same crevices were ignored. The biota of rock pools was also excluded from the present study but depressions with restricted drainage presented problems. The difficulty was resolved by ascertaining whether the fauna was more closely allied to that on nearby rock faces or to that of true rock pools in the vicinity.

The organisms studied were restricted to those of greatest ecological significance, using as criteria their abundance at one or another of the localities visited, or their abundance in New South Wales (Dakin, Bennett, and Pope 1948; R. Endean, personal experience) or on the Great Barrier Reef (Stephenson *et al.* 1931). As new elements entered the picture on proceeding northwards, all were listed as of possible significance. Even so, some reinvestigation of intermediate localities for significant (and possibly overlooked) species was necessary.

Throughout the study, the work on animals was generally restricted to the macrofauna, i.e. species more than 5 mm long. One exception was *Melaraphe acutispira*, which when abundant was conspicuous in its habitat and of interest in comparison with the other littorinids. The exclusion of smaller species was further applied to the associates of dominant species, such as the ascidian *Pyura stolonifera* and the serpulid *Galeolaria caespitosa*, which harbour numerous associated species (see Dakin, Bennett, and Pope 1948). Investigation of the ecology of the associates of such species is a task of sufficient complexity to warrant separate study.

The following procedure was adopted at each locality visited. The coastline was inspected and its general topography noted, particular attention being given to rock configuration and wave action. Main traverses were then made at points considered to be typical of the region as regards conditions of exposure to wave action, slope of rock, etc. In many cases subsidiary traverses were then made at points deliberately chosen because of extreme local variations in: (1) wave action; (2) slope of rock; (3) degree of channelling or fracturing of rock; (4) available shade.

When making a traverse some convenient reference point, usually the top of a prominent rock on or near the actual traverse, was taken. The vertical and horizontal ranges occupied by organisms or zones of organisms were then referred to this point. Vertical measurements were obtained as follows. One member of the party held upright a long stick graduated in inches. The bottom of the stick was placed on the part of the substratum the level of which was to be determined. Another member of the party placed himself so that his eye was on a level with the reference point. The member holding the graduated stick then moved a finger (held horizontally) slowly along the stick until the observer at the reference point judged that reference point, finger, and sea-sky horizon were in line. A series of reference points were taken at different levels so that distance between observer and measuring stick was never great. The height of these subsidiary reference points relative to the main one was determined in each case. Although there are some slight errors inherent in this method occasional checks by direct measurement showed that these were negligible.

Each traverse was commenced on a falling tide after first noting the time and position of high water. The water level was noted at regular intervals, and in particular the time and position of low water. From these field observations a rough curve of tidal heights was plotted. In each case these tidal data were compared with predicted tidal data obtained beforehand from the nearest recording centre. Unfortunately these centres were frequently at a considerable distance from the sites of traverses. Tidal idiosyncrasies and peculiarities of the shore profile at many localities were suspected to be responsible for many anomalies found when the field data were compared with predicted data. It should also be borne in mind that, as far as concerns the seashore animals, the tidal level (as pointed out by Colman (1933)) "at any time is that reached by the surf and not that of the real sea level at that time".

In view of the above it was decided to relate the levels on the beach occupied by organisms to effective tidal heights. Thus at each locality the tidal data, the shore profile, the degree of exposure, and the average conditions of wave action were critically examined and on this basis effective tidal heights were estimated. Although the subjective nature of this approach is realized, the picture obtained is far more instructive than that obtained from using predicted tidal heights.

The following effective tidal heights were estimated in each case:

Mean low water spring (L.W.S.)
Mean low water neap (L.W.N.)
Mean high water neap (H.W.N.)
Mean high water spring (H.W.S.)
Mean low water (M.L.W.)
Mean sea-level (M.S.L.)
Mean high water (M.H.W.)

Throughout the study, an attempt was made to make the work at least semi-quantitative on a comparative basis. (The time that could be spent at each locality was far too short to permit any counting of species on a large scale to be made.) Six grades were used for estimating the abundance of animals at particular tidal levels on each traverse, as follows:

(1) *Dominant* (*D*).—Organism present in greater numbers than any other, giving a characteristic facies to the zone occupied.

(2) *Co-dominant* (*CD*).—Two or more organisms present in approximately the same numbers, collectively giving a characteristic facies to their zone.

(3) *Subdominant* (*SD*).—Organism present in greater numbers than any species other than those attaining dominance.

(4) *Very common* (*VC*).—Organism occurring commonly but not in sufficient numbers to be placed in one of the above categories.

(5) *Common* (*C*).—Less than 40 but more than 10 specimens noted.

(6) *Present* (*P*).—No more than 10 specimens found.

This was a subjective analysis and in some of the less clear-cut cases may have led to errors. Opinions sometimes differed on the relative abundance of a particular animal at a given level or locality. This encouraged valuable cross-checking, which is of great value in work of this nature and which unfortunately was less intensive when all authors were not present.

It should be noted that the abundance of a dominant at one level is not usually equivalent to the abundance of a dominant at another level. Although the method enabled the relative abundance of animals at different levels to be established, it could not be used to compare the abundance of organisms on one traverse with those on another.

At each locality, notes on the physiography, faunistic composition, zonation, tidal data, relative abundance of animals, and habits and general ecology of the more important organisms were made in the field. As soon as possible this information was pooled and discussed, and an agreed account written up and summarized diagrammatically (viz. Fig. 6). As only a short period could be spent at each locality no attempt was made to investigate local conditions of salinity, temperature, water currents, etc., at each traverse.

Unusual specimens were collected, labelled, catalogued, and despatched to appropriate authorities (see Section XI). Some groups presented especial difficulties—the Littorinidae, Ostreidae, Chthamalidae, and Siphonariidae in particular—and field observations in some cases cast doubt on the validity of accepted species. Whilst collections were made and field identifications were checked to some extent by all the authors, responsibility for the collection and identification of various groups was assigned as follows:

Zoantharia, Annelida, Littorinidae, Neritidae, Ostreidae, Tunicata—W.S. and R.E.;
Algae—W.S. and R.K.;
Alcyonaria, Madreporaria—W.S.;
Loricata, Acmaeidae, Patellidae, Fissurellidae, Siphonariidae—R.K.;
Cirripedia, Echinodermata, remaining Mollusca—R.E.

At each traverse attention was focussed primarily on animals, and Algae were considered only when they affected the general zonation. Thus the lists of algal species are far from complete.

VI. THE SPECIES ENCOUNTERED

(*a*) *Animals*

Table 1 gives a list of the commoner animals occurring on intertidal rocks on the Queensland mainland. The list is incomplete as the identification of a few species is still awaited and some groups such as polyzoans, turbellarians, nemerteans, etc., were not collected.

TABLE 1

LIST OF COMMONER ANIMALS OCCURRING ON INTERTIDAL ROCKS ON THE QUEENSLAND MAINLAND

Species	Ecological Significance	Habitat	Normal Vertical Range	Distribution
COELENTERATA				
HYDROIDA				
Dynamena crisioides Lamouroux	V. common	Rock faces and on oysters etc.	M.S.L. to M.L.W.	Currumbin northward
ACTINIARIA				
Actinia tenebrosa Farquhar	V. common	Gutters, crevices, overhangs	H.W.N. to L.W.N.	Double Island Pt. southward
Cnidopus verater (Drayton)	V. common	Gutters, crevices	H.W.N. to L.W.N.	Double Island Pt. southward
ZOANTHARIA				
Palythoa sp.	V. common	Rock faces	L.W.N. to L.W.S.	Cannonvale, Yorkey's Knob
Zoanthus sp.	V. common	Gutters	M.S.L. to M.L.W.	Caloundra, Noosa, Pt. Vernon, Bargara, Etty Bay
MADREPORARIA				
Favites abdita (Ellis & Solander)	Present	Rock faces	Near L.W.S.	Cannonvale
Porites lutea Milne Edwards & Haime	Common	Rock faces	Near L.W.S.	Cannonvale, Shoal Pt., Coral Pt., Bustard Heads
Psammocera vaughani Yabe, Sugiyama, & Eguchi	Present	Rock faces	Near L.W.S.	Shoal Pt., Bustard Heads
Turbinaria danae Bernard	Present	Rock faces	Near L.W.S.	Cannonvale
Turbinaria peltata (Esper)	Present	Rock faces	Near L.W.S.	Cannonvale
ANNELIDA				
POLYCHAETA				
Diopatra dentata Kinberg	Common	In grit amongst boulders	L.W.N. to L.W.S.	Yeppoon southward
Galeolaria caespitosa Lamarck	Dominant	Rock faces	M.S.L. to L.W.N.	Pt. Lookout southward
Pomatoleios crosslandi Pixell	Dominant	Sheltered rock faces	M.S.L. to L.W.N.	Scarborough, Pt. Vernon northward
Sabellastate indica Savignyi	Common	Gutters	About L.W.N.	Elliott River heads southward

TABLE 1 (*Continued*)

Species	Ecological Significance	Habitat	Normal Vertical Range	Distribution
MOLLUSCA				
LORICATA				
Acanthozostera gemmata (Blainville)	Common	Crevices	M.S.L. to L.W.N.	Yeppoon, Shoal Pt., Cannonvale, Cape Edgecumbe, Etty Bay
Liolophura gaimardi (Blainville)	V. common	Depressions, crevices, rock faces	H.W.N. to L.W.N.	Throughout
Onithochiton quercinus (Gould)	Common	On coralline algae	Below M.S.L. to L.W.S.	Throughout
Poneroplax paeteliana (Thiele)	Common	Amongst algae	L.W.N. to L.W.S.	Double Island Pt. southward
Rhyssoplax excellans Iredale & Hull	Present	Rock faces	Near L.W.N.	Pt. Vernon
Rhyssoplax venusta Hull	Present	Rock faces	Near L.W.N.	Yeppoon
GASTROPODA				
Fissurellidae				
Montfortula cinerea (Gould)	Present	Rock surfaces	Near L.W.N.	Pt. Vernon
Montfortula conoidea (Reeve)	V. common	Rock surfaces	M.S.L. to L.W.N.	Shoal Pt. southward
Scutus antipodes Montfort	Present	On boulders and in crevices	L.W.N. to L.W.S.	Double Island Pt. southward
Scutus olunguis Iredale	Present	Crevices	About L.W.N.	Pt. Vernon northward
Trochidae				
Austrocochlea constricta obtusa (Dillwyn)	V. common	Ledges and depressions	H.W.N. to M.S.L.	Shoal Pt. southward
Monodonta labio (L.)	V. common	Rock surfaces	M.H.W. to M.L.W.	Pt. Vernon northward
Turbinidae				
Bellastrea sirius (Gould)	Common	In gutters	L.W.N. to L.W.S.	Bargara southward
Dinassovica militaris (Reeve)	Common	In gutters	L.W.N. to L.W.S.	Caloundra southward
Lunella mespilus Gmelin	V. common	Amongst boulders	L.W.N. to M.L.W.	Pt. Vernon northward
Turbo undulatus (Martyn)	V. common	Amongst boulders	L.W.N. to L.W.S.	Currumbin southward

TABLE 1 (*Continued*)

Species	Ecological Significance	Habitat	Normal Vertical Range	Distribution
MOLLUSCA (*Continued*)				
GASTROPODA (*Continued*)				
Neritidae				
Melanerita melanotragus (Smith)	V. common	Rock faces	H.W.N. to M.S.L.	Double Island Pt. southward
Nerita albicilla L.	Common	Amongst rubble and boulders	H.W.N. to L.W.S.	Pt. Vernon northward
Nerita annulata Reeve	Common	Amongst rubble and boulders	H.W.N. to L.W.S.	Pt. Vernon northward
Nerita chameleon L.	Common	Amongst rubble and boulders	H.W.N. to M.S.L.	Moreton Bay, Pt. Vernon, Bargara, Gatcombe Head
Nerita costata Chemnitz	V. common	Rock faces	M.H.W. to M.S.L.	Bustard Heads northward
Nerita polita L.	Common	Amongst rubble and boulders	H.W.N. to L.W.N.	Moreton Bay northward
Patellidae				
Cellana conciliata Iredale	Common	Rock faces	H.W.N. to L.W.N.	Caloundra northward
Cellana tramoserica Solander	V. common	Exposed faces	H.W.N. to L.W.N.	Double Island Pt. southward
Cellana turbator Iredale	Present	Rock faces	Below M.S.L.	Caloundra, Yorkey's Knob
Patelloididae				
Chiazacmea ater Macpherson in MS.	Present	Crevices	M.S.L. to L.W.N.	Bargara, Cannonvale, Yorkey's Knob
Chiazacmea cryptolirata Macpherson in MS.	Present	Crevices	Above M.S.L. to L.W.N.	Moreton Bay, Pt. Vernon to Townsville
Chiazacmea flammea queenslandiae Oliver	Present	Rock faces, on oysters	M.S.L. to L.W.N.	Moreton Bay, Caloundra, Yeppoon
Chiazacmea heteromorpha Oliver	V. common	Rock faces, on oysters	H.W.N. to L.W.N.	Pt. Vernon northward
Patelloida latistrigata submarmorata (Pilsbry)	Common	Rock faces	M.S.L. to L.W.N.	Yeppoon southward
Patelloida saccharina stella (Lesson)	V. common	Rock faces	M.S.L. to M.L.W.	Pt. Vernon northward
Notoacmea petterdi (Tenison-Woods)	V. common	Rock faces	About H.W.N.	Caloundra southward

TABLE 1 (*Continued*)

Species	Ecological Significance	Habitat	Normal Vertical Range	Distribution
MOLLUSCA (*Continued*)				
GASTROPODA (*Continued*)				
Littorinidae				
Melaraphe acutispira (Smith)	V. common	Rock faces	H.W.N. to M.S.L.	Bargara southward
Melaraphe melanacme (Smith)	Dominant	Rock faces	H.W.S. to H.W.N.	Moreton Bay northward
Melaraphe undulata (Gray)	Common	Rock faces	H.W.S. to H.W.N.	Moreton Bay northward
Melaraphe unifasciata (Gray)	Dominant	Rock faces	H.W.S. to H.W.N.	Double Island Pt. southward
Nodilittorina pyramidalis Quoy & Gaimard	Dominant	Rock faces	Above H.W.S.	Throughout
Bembicium keilmanseggi Zelebor				
Bembicium melanostoma (Gmelin)	V. common	Rock faces	H.W.N. to M.S.L.	Double Island Pt. southward
Bembicium melanostoma (northern form)	V. common	Rock faces	H.W.N. to L.W.N.	Pt. Vernon to Yeppoon
Bembicium sp.	Common	Rock faces	H.W.N. to M.S.L.	Coral Pt., Kissing Pt.
Peasiella tantilla (Gould)	Present	Rock faces	M.H.W. to H.W.N.	Coral Pt. northward
Planaxidae				
Planaxis sulcatus (Born)	V. common	Amongst rubble and boulders	H.W.N. to M.S.L.	Moreton Bay northward
Thaiidae				
Dicathais orbita (Gmelin)	V. common	Rock faces	M.L.W. to L.W.S.	Noosa southward
Dicathais vector Thornley	V. common	Rock faces	M.S.L. to L.W.N.	Currumbin to Double Island Pt.
Morula marginalba (Blainville)	V. common	Rock faces	M.H.W. to L.W.S.	Throughout
Thais distinguenda Dunker	V. common	Rock faces	M.S.L. to L.W.N.	Yeppoon northward
Vermetidae				
Vermetid sp.	Common	Rock faces	L.W.N. to L.W.S.	Cannonvale
Strombidae				
Conomurex luhuanus (L.)				
Conidae				
Conus lividus Hwass	Present	Depressions and gutters	About L.W.N.	Etty Bay northward

TABLE 1 (*Continued*)

Species	Ecological Significance	Habitat	Normal Vertical Range	Distribution
Mollusca (*Continued*)				
GASTROPODA (*Continued*)				
Siphonariidae				
Siphonaria atra Quoy & Gaimard	Common	Rock faces	M.S.L. to L.W.N.	Moreton Bay, Caloundra, Noosa, Yeppoon
Siphonaria elegans Iredale	V. common	Rock faces	M.H.W. to L.W.N.	Currumbin to Caloundra
Siphonaria eumelas Iredale	Common	Rock faces	M.S.L. to L.W.S.	Yeppoon to Moreton Bay
Siphonaria laciniosa L.	Common	Rock faces	M.S.L. to M.L.W.	Yorkey's Knob northward
Siphonaria marza Iredale	V. common	Rock faces	M.S.L. to L.W.S.	Moreton Bay, Currumbin northward
Siphonaria rucuana Pilsbry	Common	Rock faces	M.S.L. to M.L.W.	Cape Edgecumbe northward
Talisiphon virgulata (Hedley)	Present	Rock faces	M.S.L. to L.W.N.	Pt. Lookout southward
PELECYPODA				
Ostraeidae				
Crassostrea amasa (Iredale)	Dominant	Rock faces	H.W.N. to M.S.L.	Throughout
Crassostrea commercialis (Iredale & Roughley)				
Crassostrea echinata (Quoy & Gaimard)	V. common	Rock faces	Below H.W.N. to L.W.S.	Gatcombe Head northward
Mytilidae				
Brachyodontes hirsutus (Lamarck)	Common	Crevices	M.S.L. to M.L.W.	Throughout
Chama imbricata Broderip	Common	Rock faces, gutters	M.S.L. to L.W.N.	Cape Edgecumbe
Chama reflexa Reeve	Present	Rock faces, gutters	Near L.W.N.	Cannonvale
Perna nucleus Lamarck	V. common	Crevices	M.S.L. to L.W.N.	Pt. Vernon northward
Arthropoda				
CIRRIPEDIA				
Lepadidae				
Ibla cumingi Darwin	V. common	Crevices	H.W.N. to below M.S.L.	Pt. Vernon northward
Ibla quadrivalvis Cuvier	Common	Amongst *Galeolaria*	M.S.L. to L.W.N.	Currumbin southward

TABLE 1 (*Continued*)

Species	Ecological Significance	Habitat	Normal Vertical Range	Distribution
ARTHROPODA (*Continued*)				
CIRRIPEDIA (*Continued*)				
Chthamalidae				
Catophragmus polymerus Darwin	Common	Rock faces	H.W.N. to below M.S.L.	Currumbin southward
Chamaesipho columna Spengler				
Chthamalus antennatus Darwin	Dominant	Rock faces	M.H.W. to H.W.N.	Double Island Pt. southward
Chthamalus caudatus Pilsbry	V. common	Shaded overhangs, crevices	M.H.W. to M.L.W.	Pt. Vernon northward
Chthamalus malayensis Pilsbry	Dominant	Rock faces	M.H.W. to H.W.N.	Pt. Vernon northward
Chthamalus withersi Pilsbry	V. common	Rock faces	H.W.S. to H.W.N.	Pt. Vernon northward
Octomeris brunnea Darwin	V. common	Shaded overhangs, crevices	M.H.W. to H.W.N.	Coral Pt. northward
Balanidae				
Balanus amaryllis Darwin	Present	Rock faces	L.W.N. to below L.W.S.	Throughout
Balanus imperator Darwin	V. common	Rock faces	L.W.N. to below L.W.S.	Throughout
Balanus nigrescens Lamarck	V. common	Rock faces and gullies	L.W.N. to M.L.W.	Double Island Pt. southward
Balanus sp. nov. I Pope in MS.	V. common	Rock faces	H.W.N. to L.W.N.	Moreton Bay, Pt. Vernon northward
Balanus sp. nov. II Pope in MS.	Common	Rock faces	Below L.W.N.	Shoal Pt., Kissing Pt.
Tetraclita cerulescens (Spengler)	Present	Rock faces	About L.W.N.	Yorkey's Knob
Tetraclita purpurascens (Wood)	V. common	Shaded crevices and overhangs	M.H.W. to L.W.S.	Double Island Pt. southward
Tetraclita rosea (Krauss)	Dominant	Rock faces	Below M.H.W. to M.S.L.	Bustard Heads southward, Cannonvale, Cape Edgecumbe
Tetraclita squamosa (Bruguiere)	Dominant	Rock faces	M.S.L. to L.W.N.	Pt. Vernon northward
Tetraclita vitiata Darwin	Present	Rock faces	M.S.L. to L.W.N.	Yorkey's Knob

TABLE 1 (*Continued*)

Species	Ecological Significance	Habitat	Normal Vertical Range	Distribution
ECHINODERMATA				
ASTEROIDEA				
Patiriella calcar (Lamarck)	V. common	Gutters, rock faces	M.S.L. to L.W.S.	Currumbin southward
Patiriella exigua (Lamarck)	V. common	Amongst boulders	M.S.L. to L.W.N.	Throughout
ECHINOIDEA				
Echinometra mathaei (De Blainville)	Common	Crevices	L.W.N. to L.W.S.	Caloundra
Heliocidaris erythrogramma (Valenciennes)	Common	Crevices	L.W.N. to L.W.S.	Caloundra southward
Stomopneustes variolaris (Lamarck)	Common	Crevices	L.W.N. to L.W.S.	Yorkey's Knob northward
CHORDATA				
ASCIDIACEA				
Microcosmus claudicans Savignyi	Dominant	Rock faces	L.W.S.	Yeppoon, Shoal Pt.
Pyura stolonifera (Heller)	Dominant	Rock faces	Below L.W.N. to below L.W.S.	Double Island Pt. southward

The vertical range given for each species in Table 1 is the normal vertical range of the species under average conditions of exposure etc. The ecological significance assigned to each species is the usual significance of the species at the majority of localities investigated.

Animals that live under stones and in pools were only incidentally collected. A list of the commoner species found is given in Appendix II.

(*b*) *Algae*

The present survey has been concerned primarily with faunistic elements and, apart from a noting of the position of the "algal zone" at each locality, the flora has received a cursory treatment. A feature of algal distribution in Queensland, particularly in northern Queensland, is the apparent paucity of algae above L.W.N. In southern Queensland during the summer months there is a development of a green belt consisting of species of *Ulva* and *Enteromorpha* above the main algal zone (i.e. above L.W.N.). Unfortunately it is not known whether there is a similar development in northern Queensland waters during summer.

Collections of algae were made at most localities but some were more extensive than others. It is probable that, in most cases, only the very common species and also species with an unusual appearance were collected. In view of this no attempt was made to note the relative abundance or normal habitat of algal species. However, the *Sargassum* type of brown algae appeared to be more common on the southern Queensland coast than on the northern.

The algal species collected are recorded in Table 2 and the localities from which they were taken are noted. Of interest was the fact that *Pterocladia capillacea*, although common in southern Queensland, was not taken in northern Queensland waters. This species is common in New South Wales, and Dakin, Bennett, and Pope (1948, p. 193) note that "its characteristic feature is its love of the pounding surf and the most exposed of all rock surfaces". Of interest too is the apparent absence in Queensland of such common New South Wales algae as *Hormosira banksi* (Turner) Decaisne, *Ecklonia radiata* (Turner) J. Agardh, and *Phyllospora comosa* (Labill.). According to Dakin, Bennett, and Pope (1948) the latter species is not found north of about lat. 31° 30′ S.

VII. BASIC ZONATION PATTERNS ON THE ROCKY COAST OF QUEENSLAND

It was found that the dominant organisms and the basic zonation changed with latitude. Therefore two patterns, typical of the position in southern and northern Queensland respectively, are depicted. The zonation at other localities along the coast is referred to these and similarities or differences, or both, are noted.

(*a*) *Southern Queensland*

Figure 6 shows graphically the zonation and abundance of the ecologically important organisms on a traverse made at Currumbin, where conditions are reasonably typical of those prevailing in southern Queensland generally. Tidal levels on the vertical axis are the effective tidal levels operating, allowance having been made for the average effects of wave action at the site investigated. Each

TABLE 2

ALGAL SPECIES COLLECTED

Species	Currumbin	Pt. Lookout	Caloundra	Noosa	Bargara	Yeppoon	Shoal Pt.	Cannonvale	Cape Edgecumbe	Kissing Pt.	Etty Bay	Yorkey's Knob	Whitecliffs
CHLOROPHYTA													
Acetabularia sp.							×						
Caulerpa cupressoides (Vahl) Agardh							×						
C. racemosa (Forskål) W.v. Bosse							×						
C. sp.	×						×						
C. sedoides (R. Brown) Agardh							×						
C. sp.	×	×			×								×
Cladophora pellucida Kützing												×	
Codium sp.		×	×			×							
Enteromorpha sp.	×				×	×							
Halimeda sp.		×											
Udotea sp.							×						
Ulva sp.	×				×	×							
Valonia aegagropila C. Agardh												×	
Valoniopsis pachynema (Martens) Boergesen												×	
PHAEOPHYTA													
Chnoospora pacifica J. Agardh		×		×									
Colpomenia sinuosa (Roth) Derbes & Solier							×	×					
Cystophyllum muricatum (Turner) J. Agardh							×	×				×	
Dictyota volubis Kützing							×						
Dictyota sp.		×					×						
Dictyopteris sp.							×						
Ectocarpus sp.						×							
Hydroclathrus clathratus (Bory) Howe							×						
Padina sp.	×				×	×	×						
Sargassum decurrens (R. Brown) C. Agardh							×						
Sargassum spp.	×	×	×	×	×	×	×		×			×	
Spacelaria sp.									×				

TABLE 2 (*Continued*)

Species	Currumbin	Pt. Lookout	Caloundra	Noosa	Bargara	Yeppoon	Shoal Pt.	Cannonvale	Cape Edgecumbe	Kissing Pt.	Etty Bay	Yorkey's Knob	Whitecliffs
RHODOPHYTA													
Acanthophora sp.													×
Calaglossa leprieurii (Montagne) J. Agardh										×			
Catanella sp.											×		
Centroceros clavulatum (C. Agardh) Montagne									×			×	
Ceramium sp.						×							
Champia parvula (Agardh) Harvey													
Desmia sp.							×						
Galaxaura sp.							×		×				
Gelidiopsis sp.												×	
Gelidium sp.												×	×
Hypnea sp.		×				×	×					×	
Jania sp.	×	×		×	×	×		×	×			×	×
Laurencia sp.	×	×	×	×		×		×	×				
Leveillea jungermannoides (Martens & Hering) Harvey								×	×				
"Lithothamnion"	×	×	×	×	×	×		×		×	×	×	×
Lophosiphonia obscura (Agardh) Falkenberg								×					
Lophosiphonia sp.										×		×	
Pterocladia capillacea (Gmelin) Bornet & Thuret	×	×	×	×									

important species is represented by a vertical line whose position and length indicates its vertical range with reference to effective tidal heights. The width of the line indicates the comparative degree of abundance of the species.

The sequence of dominant organisms providing the basic zones from the supralittoral to the infralittoral was:

(i) Upper littorinid or *Nodilittorina* zone.—*N. pyramidalis* was dominant. Apart from terrestrial species this was the sole inhabitant of the spray region above H.W.S.

(ii) Lower littorinid or *Melaraphe* zone.—*M. unifasciata* was dominant from just below H.W.S. to M.H.W.

(iii) Upper barnacle or *Chthamalus* zone.—*C. antennatus* and *Melaraphe unifasciata* were co-dominants on traverse depicted, from M.H.W. to half-way between M.H.W. and H.W.N. In most situations *C. antennatus* was dominant.

(iv) Lower barnacle or *Tetraclita* zone.—*T. rosea* was dominant from a point approximately half-way from M.H.W. to H.W.N. and extending to a point just below M.S.L.

(v) Serpulid or *Galeolaria* zone.—*G. caespitosa* was dominant from just below M.S.L. to about L.W.N.

(vi) Algal-ascidian zone.—Although in Figure 6 algae are depicted as dominants from L.W.N. to M.L.W. and then co-dominant with the ascidian *Pyura stolonifera* to below L.W.S., on other traverses the ascidian was the dominant organism from L.W.N. to below L.W.S.

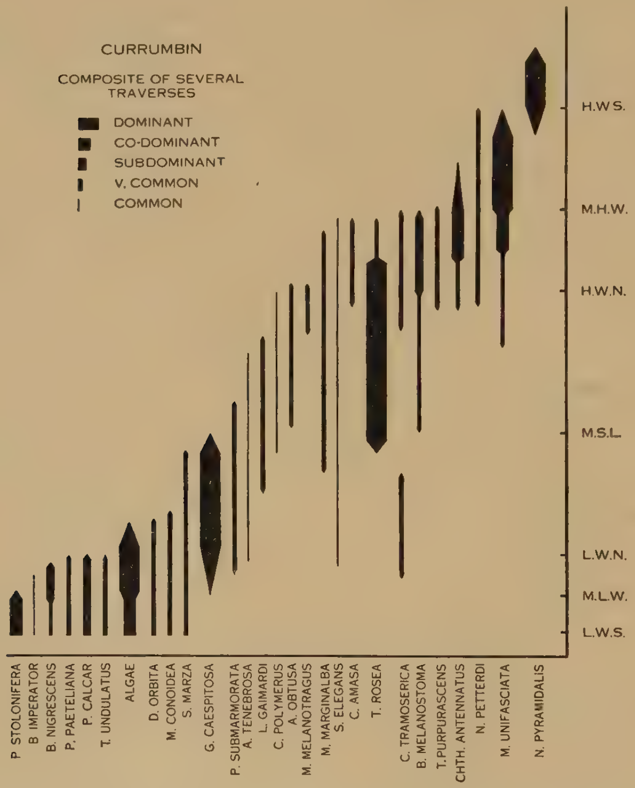

Fig. 6.—Diagrammatic representation of zonation and abundance of organisms at Currumbin.

This basic zonation (Plate 2, Figs. 1 and 2; Plate 3, Figs. 1 and 2) resembled that occurring in New South Wales as described by Dakin, Bennett, and Pope (1948). However, the barnacle picture was somewhat modified. In New South Wales the small barnacle *Chamaesipho columna* occurred in a broad zone between the *Chthamalus* zone and the *Galeolaria* zone. In this broad zone the larger barnacles *Tetraclita rosea* and *Catophragmus polymerus* were also found. The relative abundance of these barnacles varied according to the degree of exposure to wave action and the configuration of the rock. Usually "one finds the sequence, *Galeolaria*, *Catophragmus-Tetraclita*, *Tetraclita*, *Chamaesipho-Chthamalus* (passing from low to higher levels) in fairly exposed places and *Galeolaria*, *Chamaesipho*, *Chthamalus* on more sheltered rock shore margins" (Dakin, Bennett, and Pope 1948, p. 200). In southern Queensland *Chamaesipho columna* was not found and *Catophragmus polymerus* reached the northern limits of its range, few specimens being observed. *Tetraclita rosea*, however, was particularly well developed, and formed usually the most conspicuous zone on the seashore. Another difference between the New South Wales and southern Queensland pictures was the absence in Queensland of *Ecklonia radiata* (Turn.) and *Phyllospora comosa* (Labill.) which in New South Wales formed a zone—the kelp zone—below the *Pyura* zone.

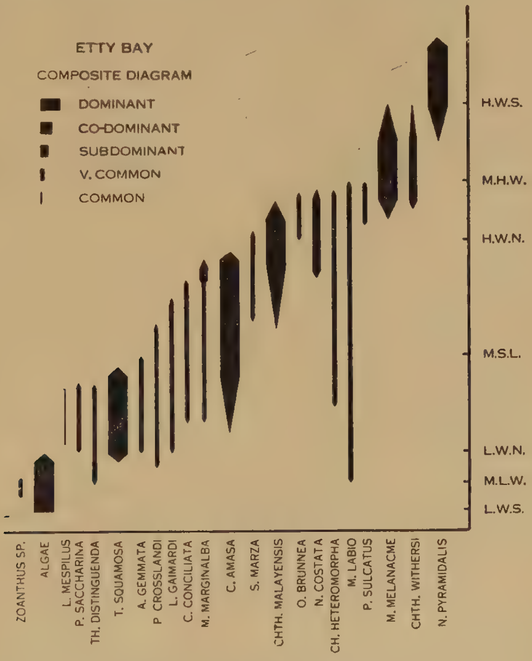

Fig. 7.—Diagrammatic representation of zonation and abundance of organisms at Etty Bay.

(*b*) *Northern Queensland*

Figure 7 shows the zonation of the major biotic elements at Etty Bay, near Innisfail. The sequence of dominant organisms was:

(i) Upper littorinid or *Nodilittorina* zone.—*N. pyramidalis* dominated the spray region above H.W.S.

(ii) Lower littorinid or *Melaraphe* zone.—*M. melanacme* was dominant in the region from H.W.S. to about a third of the way from M.H.W. to H.W.N.

(iii) Upper barnacle or *Chthamalus* zone.—The small barnacle *C. malayensis* was dominant from the lower limit of dominance of *Melaraphe melanacme* to slightly below H.W.N.

(iv) Oyster zone.—A conspicuous zone was formed by the oyster *Crassostrea amasa* from a point just below H.W.N. to a point about a sixth of the way from M.S.L. to L.W.N.

(v) Lower barnacle or *Tetraclita* zone.—The region from the bottom of the oyster zone to just below L.W.N. was dominated by the large slate-grey barnacle *T. squamosa*.

(vi) Algal zone.—Algae dominated the region from just below L.W.N. to below L.W.S.

(c) *Comparison of the Basic Zonation of Northern and Southern Queensland*

Although the littorinid zones in northern and southern Queensland occupied the same region of the shore with respect to tidal height, *Melaraphe unifasciata*, the dominant animal of the lower littorinid zone, was replaced in the north by *Melaraphe melanacme*.

The *Chthamalus* zone in northern Queensland, which was occupied by *Chthamalus malayensis* (Plate 6, Fig. 2), extended further down the beach and was usually more conspicuous, especially on vertical faces, than the corresponding zone in southern Queensland, which was occupied by the closely related *Chthamalus antennatus*.

In northern Queensland the oyster *Crassostrea amasa* was the most conspicuous element in the littoral fauna, and frequently the rock surface in the region from H.W.N. to M.S.L. was completely obscured by a pavement of oysters (Plate 7, Fig. 1). This contrasted strongly with the position in southern Queensland, where this region of the seashore was occupied by the pinkish barnacle *Tetraclita rosea*.

Another outstanding difference in the zonation patterns in northern and southern Queensland concerned the region between M.S.L. to L.W.N. In southern Queensland south of Point Lookout, this region was dominated by the calcareous tubes of the serpulid *Galeolaria caespitosa*, but in northern Queensland it was characterized by the presence of the large barnacle *Tetraclita squamosa* (Plate 7, Fig. 2). It should be mentioned that in northern Queensland a serpulid, *Pomatoleios crosslandi*, did occur in this zone. On the reverse face of rocks in sheltered localities, the encrusting calcareous tubes of this worm had a superficial resemblance to those of *Galeolaria caespitosa*. However, the occurrence of *P. crosslandi* is somewhat sporadic and it was of importance only on sheltered traverses.

In northern Queensland the algal-ascidian zone, a characteristic feature of southern Queensland zonation, was represented only by Algae. Although the species composition of this zone was obviously different from that of southern Queensland, the upper limits of the algae-dominated region of the shore in relation to effective tidal height were approximately the same.

(d) *Relation of Zones to Tidal Level and Exposure to Air*

Exposure to air as a factor of major importance in determining the vertical zonation of organisms was first discussed by Colman (1933), and subsequently by Stephenson (1941), Chapman (1943), Doty (1946), and Evans (1947*a*, 1947*b*) amongst others. For the importance of this factor at any locality to be critically evaluated, accurate tidal data for that locality are necessary. In southern Queensland such data are available for Point Danger, about 10 miles south of Currumbin. After discussion with the Queensland Department of Harbours and Marine, it is considered that these data can be used without modification for Currumbin.

A 29-day tidal cycle (September-October 1948) was selected from these data. (It was considered that tidal conditions prevailing during this cycle approximated average conditions for the year.) The periods of time during each successive tide that particular levels (a foot apart) were exposed during this cycle were added together and calculated as a percentage of the total time. The percentage exposure figures so obtained were plotted against tidal height (Fig. 8). It can be seen from this graph that the greatest rates of change in percentage exposure to air from one level to another occurred at approximately M.L.W. and M.H.W. This result is similar to that obtained by Knox (1953) for a New Zealand locality but differs from the levels given by Chapman (1943) for certain localities in Britain. Colman (1933) noted that the splash from breaking waves raised tide marks on the seashore above their predicted level. In order to correlate tidal data with the vertical distribution of species Colman allowed 2 ft for the "splash zone" and added this value to the predicted height of each tidal level.

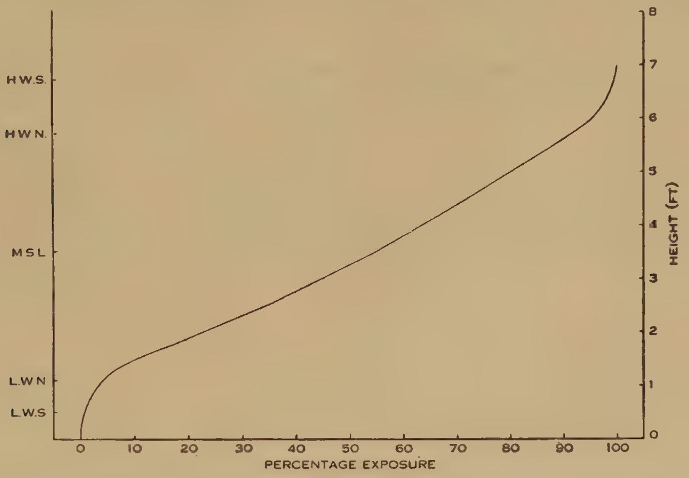

Fig. 8.—Percentage exposure to air at Point Danger; from tidal data supplied by the Queensland Department of Harbours and Marine.

In southern Queensland there is considerable wave action and it was estimated that 6-7 ft should be added to the predicted tidal range to allow for the combined effects of surge and splash. Also, measurements revealed that the allowance that should be made for these factors varied according to the height on the beach. A far greater allowance was necessary at levels between H.W.N. and H.W.S. than at other levels. This can be correlated with the general profile of the intertidal region.

It is usual in southern Queensland for vertical and near-vertical rock faces to front the sea in the upper regions of the intertidal area. Below these regions there is usually a sloping accumulation of boulders or a wave-cut sloping beach with boulders at the foot.

Figure 9 shows the profile of the beach at Currumbin where a traverse, the zonation of organisms on which is depicted in Figure 6, was made. At high tide, waves break at a variable distance offshore, sweep in shorewards, and cascade over the outlying rocks near L.W.S. They then surge over the sloping rock faces of the mid littoral and impinge on the steep rock faces in the upper regions of the intertidal area. Water is as a result hurled many feet into the air, and this results in a splash zone of considerable extent being formed in the upper region of the littoral area. This accounts for the difference of 3 ft 6 in. between the effective height of the region between H.W.N. and H.W.S. as shown in Figure 6 and the predicted height for this region (Fig. 8). At low tide, waves meet the rocky outliers, causing spray to be flung upwards, and consequently effective tidal levels in the region from approximately L.W.S. to L.W.N. are greater than those predicted by about 1 ft 6 in. On the other hand, the region between effective L.W.N. and effective H.W.N. occupies a vertical height of about 6 ft 6 in., which is only 1 ft 6 in. in excess of the predicted range. This can be accounted for by the fact that the relative lack of steep faces in this area minimizes splash.

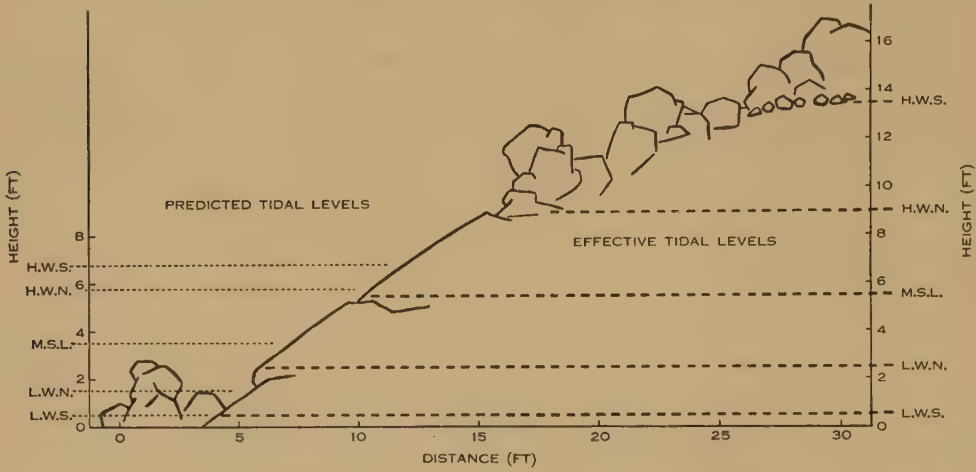

Fig. 9.—Beach profile at Currumbin, showing the relationship of predicted and effective tidal levels.

A study of the upper levels of organisms depicted in Figure 6 reveals that a large proportion of the species listed extended no further up the beach than M.H.W., corresponding to about 98 per cent. exposure to air (Fig. 8). This must be a critical level on the shore, and it is to be noted that the greatest rate of change in percentage exposure to air from one level to another occurs at M.H.W. and M.L.W. Although it would be expected that M.L.W. would also be a critical level, the only organism depicted as having its upper level at this point is the ascidian *Pyura stolonifera*. However, this species may extend as high as L.W.N., as do the species of algae comprising the main algal zone.

The upper limits of the basic zones in southern Queensland correspond with the following percentage exposures:

(i) Upper littorinid zone.—100 per cent. exposure,

(ii) Lower littorinid zone.—Almost 100 per cent. exposure,

(iii) *Chthamalus* zone.—98 per cent. exposure,

(iv) *Tetraclita* zone.—95 per cent. exposure,

(v) *Galeolaria* zone.—50 per cent. exposure,

(vi) Algal-ascidian zone.—4 per cent. exposure.

Accurate tidal data for the northern Queensland localities where traverses were made are not available. Consequently a graph showing percentage exposures to the air of various levels in the intertidal area could not be drawn up. It was estimated that it would be necessary to allow for a splash zone of only 1-2 ft when ascertaining effective tidal levels in northern Queensland waters.

VIII. Variations in Basic Zonation and Faunistic Composition

Some of the important environmental factors affecting zonation and faunistic composition in southern and northern Queensland respectively are listed below. One case of variation which cannot be related to obvious environmental factors is separately listed.

(*a*) *Southern Queensland*

(i) *Geological Nature of Substratum.*—The zonation and species composition of animals did not appear to be affected by the chemical nature of the intertidal rock.

(ii) *Slope of Substratum.*—Zonation was best observed on vertical and near-vertical faces. On gently sloping rock the extent of each zone is far greater than on vertical faces. Because of the increased area of rock exposed, irregularities in the rock surface are more likely to be encountered. These tend to confuse the picture, and zonation is therefore not as well displayed as on vertical faces. Moreover, there are differences in the faunistic composition. On gently sloping rock surfaces, e.g. at Caloundra, the barnacle *Tetraclita rosea* was poorly represented whilst the limpet *Cellana tramoserica* (Plate 4, Fig. 2) was abundant; and the region from H.W.N. to just below M.S.L. could be referred to as a limpet zone instead of a lower barnacle zone. On the other hand, on vertical and near-vertical surfaces the barnacle zones were extremely well developed and *C. tramoserica* was virtually absent. Apart from littorinids in the uppermost zones (and the predaceous whelks which prey on the barnacles), gastropods occurred in reduced numbers on steeper slopes. Zonation patterns are illustrated in Figure 10.

At Currumbin there is a rock platform which has been cut apparently by wave action. The surface of this platform, with the exception of a large mound of rock at the north-west (sheltered) side, is awash at about M.H.W. but waves sweep across it well before M.H.W. is reached. It was found that among the upper littoral browsing gastropods a *horizontal zonation* was in evidence. *Bembicium melanostoma* was present nearest the edge of the platform, next came *Melanerita melanotragus*, and furthest away from the edge was *Austrocochlea constricta obtusa*. It is tentatively suggested that this disposition is related to the ability of the animals to withstand wave action, with resistance to desiccation playing a minor role as most of the platform is flooded at about the same time.

(iii) *Dissection of Substratum.*—At localities where there were channels and gullies near L.W.N., and consequently turbulent water, the abundance of the large barnacle *Balanus nigrescens* was enhanced. Such situations occur at Point Lookout and Double Island Point, and at the edge of the rock platforms at Currumbin and Caloundra. In such places the turban *Dinassovica militaris* and the tent-shell *Bellastrea sirius* were found. Their heavy shells seemed to become wedged in crevices and against projections in these gullies. Anemones such as *Actinia tenebrosa* were found frequently along the sides of these gullies.

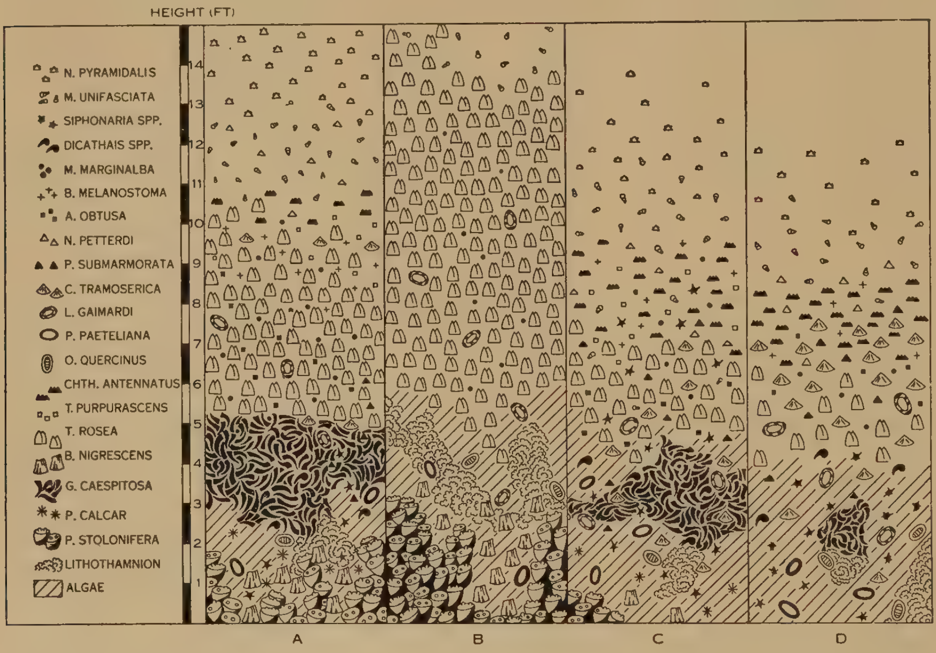
HEIGHT (FT)
N. PYRAMIDALIS
M. UNIFASCIATA
SIPHONARIA SPP.
DICATHAIS SPP.
M. MARGINALBA
B. MELANOSTOMA
A. OBTUSA
N. PETTERDI
P. SUBMARMORATA
C. TRAMOSERICA
L. GAIMARDI
P. PAETELIANA
O. QUERCINUS
CHTH. ANTENNATUS
T. PURPURASCENS
T. ROSEA
B. NIGRESCENS
G. CAESPITOSA
P. CALCAR
P. STOLONIFERA
LITHOTHAMNION
ALGAE
14
13
12
11
10
9
8
7
6
5
4
3
2
1
A
B
C
D

Fig. 10.—Typical zonation patterns in southern Queensland. *A*, medium slope, medium exposure; *B*, nearly vertical, very exposed; *C*, steeply sloping, semi-sheltered; *D*, gently sloping, semi-sheltered.

The abundance of browsing gastropods was always affected by the amount of rubble and small boulders at a particular locality and it was amongst such assemblages that most of the rarer animals listed in Table 1 were encountered. In general, it could be said that the presence of rubble and small boulders at any locality led to an increase in the numbers of browsing gastropods and that there was a concomitant decrease in the numbers of barnacles.

Pits and small depressions in the surface of the rock substratum were favoured habitats of littorinids and, other factors being roughly equivalent, the abundance of these animals was related to the availability of such depressions. The gastropod *Austrocochlea constricta obtusa* showed a tendency to aggregate in damp depressions and around the edges of small pools.

The availability of crevices near L.W.N. determined the abundance of the sea urchin *Heliocidaris erythrogramma*; and anemones, sponges, and tunicates were always well developed on the under-side of overhanging rocks if these were near low water.

(iv) *Degree of Wave Action.*—Where wave action was excessive, as on the most exposed traverse at Point Lookout, *Pyura stolonifera* and *Balanus nigrescens* were abundant but the serpulid *Galeolaria caespitosa* was absent and in its place a band of pink "lithothamnion" was found. On the sheltered traverse at Point Lookout, *Pyura stolonifera* and *Balanus nigrescens* were absent and in the region they normally occupy a thick mat of brown and green algae was found. On this traverse also, the *Galeolaria* zone was well developed but "lithothamnion" was patchy and restricted to vertical faces.

Although the relative abundance of *Pyura stolonifera* and *Galeolaria caespitosa* was related to the degree of wave action at any locality, the upper limits of the respective zones occupied were related to effective tidal levels, which below M.S.L. approximate the predicted levels on a calm day. At exposed localities where there is usually a moderate or rough sea running, effective tidal levels above M.S.L. are much higher than if calm conditions prevailed. Consequently the height reached by the *Tetraclita*, *Chthamalus*, and littorinid zones was dependent on wave surge combined with slope of rocks. Thus at Currumbin the zone of *T. rosea* extended for about 5 ft above M.S.L., while on the exposed traverse at Point Lookout it extended to 10 ft above M.S.L. In fact the width of the *T. rosea* zone at all localities was a direct function of the degree of wave surge, the greater the surge the wider being the zone.

On the most exposed traverse at Point Lookout, *Chthamalus antennatus* was not observed; nor was it common at other localities in situations which received the full force of the waves. On semi-sheltered traverses made at Currumbin and Noosa it was commonest in splash areas and drainage crevices above H.W.N., and on sheltered traverses at Point Lookout and Noosa it was a dominant form from H.W.S. almost to M.S.L. Occasionally specimens of this barnacle were found just above H.W.S., and such specimens must only be covered with water during heavy storms or at extreme high water springs.

At Currumbin the *Melaraphe unifasciata* zone had a width of about 3 ft, but at the exposed traverse at Point Lookout its width was about 25 ft. The zone was chiefly in the splash and trickle area. In sheltered regions, e.g. on the sheltered traverses made at Point Lookout and Noosa, *M. unifasciata* extended down almost to L.W.N., and it would seem that the severity of wave action determined the lower level of this littorinid to a marked degree.

Where conditions were such that there was much splash and spray the development of *Nodilittorina pyramidalis* was enhanced. On the very exposed traverse at Point Lookout this species occurred up to approximately 50 ft above M.H.W.

(v) *Shade.*—The barnacle *Tetraclita purpurascens*, which was found at all levels on the beach, preferred the shade of overhanging boulders; and the presence or absence of such situations determined the abundance of the barnacle.

(vi) *Specific Interactions.*—Wherever the carnivorous thaid *Morula marginalba* was abundant, as at certain regions at Caloundra, the population of living *Tetraclita rosea* was reduced in number although the calcareous exoskeletons of these remained attached to the rock (Plate 4, Fig. 1).

The disappearance of *Galeolaria caespitosa* from the intertidal picture had interesting consequences. The lower level of the *Tetraclita* zone seemed to be determined by the presence of the serpulid. Where the latter was abundant (e.g. at Currumbin), *T. rosea* rarely extended further down the beach than the upper limit of the *Galeolaria* zone. However, where the serpulid was absent (e.g. at Double Island Point) the barnacle extended as a sheet from H.W.N. to L.W.N. It would seem, therefore, that it was the upper level of the *Galeolaria* zone that usually determined the lower level of the *Tetraclita* zone.

Two species of *Dicathais* were encountered in southern Queensland. At Currumbin the typical "cart-rut shell" of the New South Wales coast, *D. orbita*, was common from about half-way between H.W.N. and M.S.L. to L.W.S. It was commonest—frequently a subdominant—from M.S.L. to L.W.S. Centred at a point about half-way from M.S.L. to L.W.N. were small clusters of a different species of *Dicathais*, *D. vector*. At Point Lookout and Caloundra both were represented in approximately equal numbers, *D. orbita*, however, being found nearer low-water mark than *D. vector*. At Noosa and Double Island Point *D. vector* was a subdominant from M.S.L. to almost L.W.N. On the other hand only a few specimens of *D. orbita* were collected at L.W.N. It is noteworthy that the increase in the numbers of *D. vector* could be correlated with the absence of the serpulid *Galeolaria caespitosa*. *D. vector* occurred in the zone on the beach normally occupied by the encrusting tubes of this form, which "cut out" at Point Lookout.

Examination of the bases of the tests of numerous specimens of the ascidian *Pyura stolonifera*, the upper limit of which in many places abutted the *Galeolaria* zone, has revealed the presence of the calcareous tubes of the serpulid embedded in the test (Endean 1955). This "growing over" process undoubtedly plays a part in preventing *G. caespitosa* from extending further down the beach towards low water; and it would appear that in areas where these two sedentary forms abutted one another, the lower level of the *Galeolaria* zone was determined by the upper level of the *Pyura* zone.

It was also observed that in more sheltered areas where the *Pyura* association was replaced by an algal mat, the presence of this mat seemed to be the effective agent in determining the lower limits of the *Galeolaria* zone. The algal zone had a particularly sharp upper level, and at the junction of the two zones an immediate diminution in the numbers of the serpulid occurred. On a traverse made on the sheltered side of Point Lookout headland the algae were somewhat patchy, and clumps of *G. caespitosa* were found as low as M.L.W. Apparently the presence of algae was inimical to the adult serpulid or to the settlement of its larvae—probably the latter—as the adult *Galeolaria* immediately adjacent to the algae always appeared quite healthy.

(*b*) *Northern Queensland*

(i) *Nature of Substratum.*—As in southern Queensland the chemical nature of the intertidal rock, which varied considerably from place to place (see Appendix I), had no observable effect on the zonation and faunistic composition.

(ii) *Slope of Substratum.*—On gently sloping rocks, as on the sloping traverse at Whitecliffs, the tops of the boulders between H.W.N. and M.S.L. were frequently invisible beneath a pavement of oysters. On the steep smooth cliff face at Whitecliffs the oysters were much reduced in abundance, whilst the barnacle *Chthamalus malayensis* extended down into and dominated the zone normally dominated by the oyster. This lowering of the level of the *Chthamalus* zone and decrease in the number of oysters occurred at all points where steeply sloping or vertical rocks were found (e.g. Coral Point, Cape Edgecumbe). Typical zonation patterns are illustrated in Figure 11.

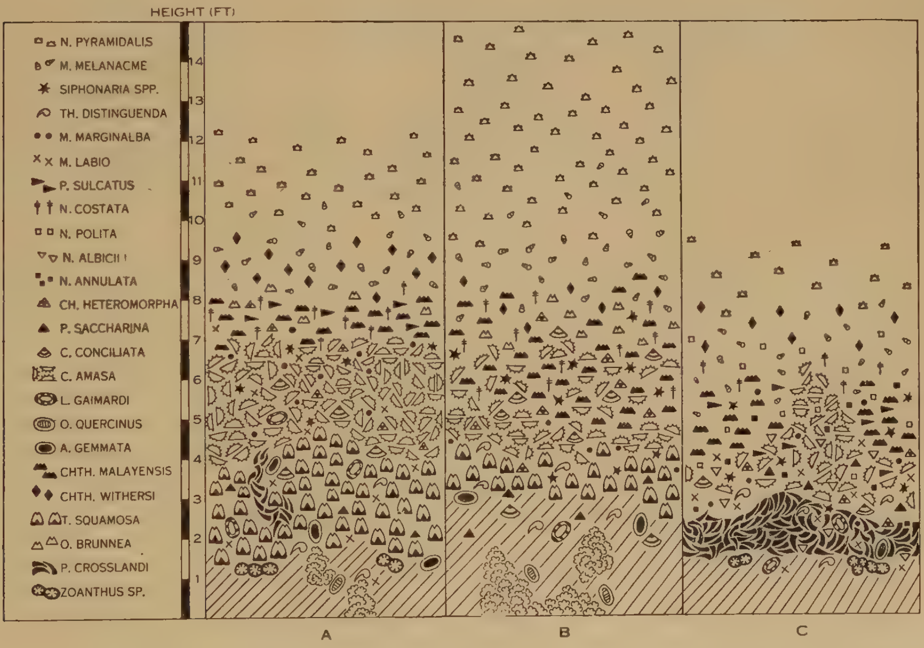
HEIGHT (FT)
N. PYRAMIDALIS
M. MELANACME
SIPHONARIA SPP.
TH. DISTINGUENDA
M. MARGINALBA
M. LABIO
P. SULCATUS
N. COSTATA
N. POLITA
N. ALBICII
N. ANNULATA
CH. HETEROMORPHA
P. SACCHARINA
C. CONCILIATA
C. AMASA
L. GAIMARDI
O. QUERCINUS
A. GEMMATA
CHTH. MALAYENSIS
CHTH. WITHERSI
T. SQUAMOSA
O. BRUNNEA
P. CROSSLANDI
ZOANTHUS SP.
14
13
12
11
10
9
8
7
6
5
4
3
2
1
A
B
C

Fig. 11.—Typical zonation patterns in northern Queensland. *A*, medium slope, medium exposure; *B*, steeply sloping, exposed; *C*, gently sloping, semi-sheltered.

(iii) *Dissection of Substratum.*—In most places where the beach shelved gradually there was an accumulation of rubble in the intertidal region, as for example, at Bargara, Shoal Point, and sheltered traverses at Yeppoon and Yorkey's Knob. Amongst this rubble large numbers of browsing gastropods (e.g. *Planaxis sulcatus*, *Monodonta labio*, *Nerita* spp.) were found and there seemed to be a direct relationship between the amount of rubble and the abundance of these species. The turban shell *Lunella mespilus* was found amongst rubble which occurred below L.W.N.

The availability near high-water mark of crevices and gullies subject to splash influenced the abundance of the barnacle *Chthamalus withersi*. Where such situations were common the barnacle was abundant. Likewise, the presence of narrow crevices in the intertidal area determined the relative abundance of such typical crevice-dwelling forms as *Ibla cumingii* and *Perna nucleus*.

The large chiton *Acanthozostera gemmata*, which occurred from M.S.L. to L.W.N., enlarged small depressions in the rocks to which it retired during the day, feeding only at night.

(iv) *Exposure to Wave Action.*—On a traverse made on the sheltered side of a headland at Yeppoon the barnacle *Tetraclita squamosa* was rare but the serpulid *Pomatoleios crosslandi* was a dominant in the zone normally occupied by the barnacle. A similar picture was obtained at the somewhat sheltered localities of Shoal Point and Cannonvale, and at a sheltered traverse made at Yorkey's Knob. At semi-exposed and exposed localities the picture was reversed and *Tetraclita squamosa* was a dominant forming the typical northern Queensland *Tetraclita* zone, whilst the serpulid was rare or entirely absent.

The barnacle *Balanus imperator* seemed to prefer more exposed situations but its occurrence was somewhat sporadic.

As in southern Queensland the extent of wave action determined the height reached by the *Chthamalus* zone. Where wave action was greater than usual *Chthamalus withersi* extended further up the beach. However, as mentioned earlier, wave action is not as potent a factor in causing variations in the basic zonation pattern in northern Queensland as it is in southern Queensland.

(v) *Shade.*—Between the extremes of M.H.W. and M.L.W. the barnacle *Chthamalus caudatus* occurred at any level of the beach where shade was provided by gutters, crevices, boulders, or overhangs. The height at which boulders were found on the beach influenced the general zonation picture to some extent. Usually it was only near high-water mark that there was an accumulation of boulders and for this reason *C. caudatus* was considered initially to be an essentially upper littoral animal. However, a further visit to Point Vernon, where there was an accumulation of boulders near L.W.N., revealed that *C. caudatus* was common on the shaded sides of these boulders. Probably the virtual absence of predators above H.W.N. also affected the abundance of the barnacle.

Another barnacle found only in shaded situations was the eight-valved *Octomeris brunnea*. However, this species was rarely found below H.W.N. even where boulders were present lower down the beach.

(vi) *Turbidity.*—Few data on turbidity of the water at Queensland coastal localities are available, but at most localities it was evident that the water was distinctly turbid, certainly more so than the waters of southern Queensland. At Cannonvale, Shoal Point, and Cape Edgecumbe where corals and soft corals were encountered the water was murky with contained sediment. The Low Isles Expedition (Marshall and Orr 1931) found that as long as corals were not smothered by an accumulation of sediment building up on the substratum around them, most could cope with a constant rain of sediment from above.

However, on the mainland coast it is difficult to assess the real importance of the turbidity factor, particularly near river outlets, because the occurrence of sediment-laden water may be linked with a reduction in salinity. It is evident, however, that animals found commonly on the mainland shores of northern Queensland can tolerate very turbid water.

(vii) *Salinity.*—As mentioned earlier, few data are available on the salinity of the water near the mainland in northern Queensland. It was considered, however, that the salinity of the water near the mouths of rivers would at times, particularly during the period of the summer rains, be much reduced. Thus animals on the rocks at Yeppoon, Cape Capricorn, Gatcombe Head, Point Vernon, and Kissing Point must be subjected periodically to a lowered salinity.

It was, therefore, noteworthy that at these localities the small barnacle *Balanus* sp. nov. I was very common, whilst it was rare or entirely absent at the other localities visited. This barnacle was also found growing on the trunks of mangroves in the lower reaches of the Mary River. It is probable, therefore, that it is essentially an estuarine species.

On the other hand, the barnacle *Chthamalus malayensis* was not observed at these localities, except for a few specimens at Kissing Point. Most of the other animals normally found on rocky shores in northern Queensland were represented at these localities, and it is evident that they can withstand a marked reduction in salinity.

(viii) *Migration with Tides.*—It was observed that the gastropod *Nerita costata* migrated from M.H.W. to below H.W.N. as the tide fell, and a reverse migration occurred as the tide rose.

(ix) *Occurrence of Juveniles and Adult Specimens at Different Levels on the Shore.*—Immature specimens of the thaid *Thais distinguenda* occurred constantly at a lower level than adults. On the other hand specimens of the oyster *Crassostrea echinata* that occurred above L.W.N. were all of small size and retained spinous processes, a juvenile characteristic. It was only near L.W.N. and below that typical adult specimens of this species were found.

(x) *Specific Interactions.*—In certain habitats at Whitecliffs the tops of the boulders between H.W.N. and M.S.L. were hidden by a pavement of oysters. Individual oysters abutted each other so closely that many had an almost tubular shape and there was no space for the attachment of other organisms. In other habitats between H.W.N. and M.S.L., barnacles (*Chthamalus malayensis*) were at many localities extremely dense, and there was no substratum exposed at this level for the attachment of other sedentary forms. Again, in other areas, where the serpulid *Pomatoleios crosslandi* was well developed, the encrusting tubes of this species completely covered the rock and in some cases the covering layer of calcareous tubes was almost an inch in thickness.

Although in the above cases insufficient substratum was exposed for the attachment of other sedentary forms, a few interesting associations were observed. A small limpet, *Chiazacmea heteromorpha*, was commonly found on the upper valves of the oysters. As it is an algal feeder it may be of importance in preventing algae from forming a mat over the oysters. A small brown unidentified anemone was often found growing on and amongst the oysters. The calcareous tubes of the serpulid *Pomatoleios crosslandi* were usually closely invested with a hydroid, *Dynamena crisioides*.

The thaid *Morula marginalba*, which in southern Queensland preyed on *Tetraclita rosea*, utilized *Chthamalus malayensis* for food in northern Queensland. It should be noted that the latter barnacle extends much further down the beach than does its southern counterpart, *C. antennatus*, which usually occurs at too high a level to be preyed upon greatly by the thaid.

Although *M. marginalba* was frequently found amongst specimens of the northern Queensland barnacle *Tetraclita squamosa* it did not seem to utilize this barnacle for food. Presumably it was not capable of penetrating the thick valves of this species. However, *T. squamosa* was preyed on by a large thaid, *Thais distinguenda*.

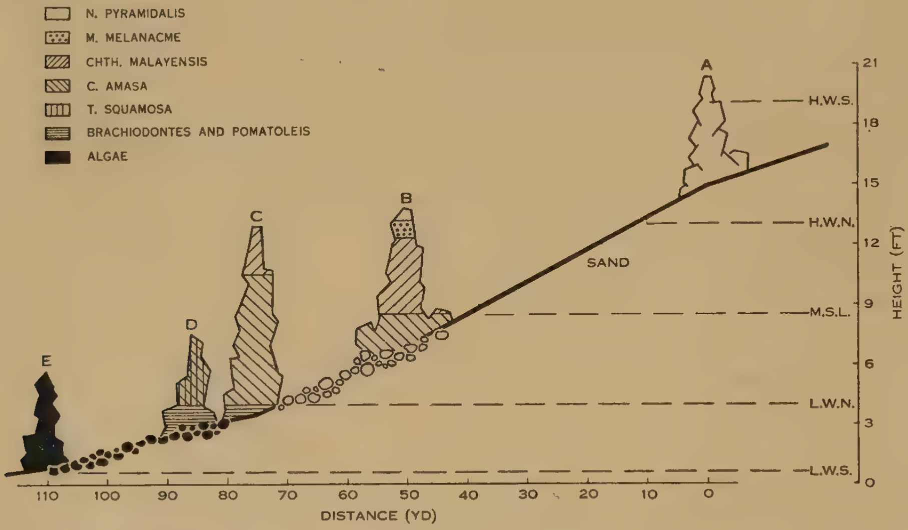
N. PYRAMIDALIS
M. MELANACME
CHTH. MALAYENSIS
C. AMASA
T. SQUAMOSA
BRACHIODONTES AND POMATOLEIS
ALGAE
A
B
C
D
E
SAND
H.W.S.
H.W.N.
M.S.L.
L.W.N.
L.W.S.
21
18
15
12
9
6
3
0
HEIGHT (FT)
110
100
90
80
70
60
50
40
30
20
10
0
DISTANCE (YD)

Fig. 12.—Zonation on rock faces at Shoal Point, Mackay. Vertical scale = horizontal scale × 10.

The chiton *Onithochiton quercinus* was found in both northern and southern Queensland and its occurrence seemed to be closely linked with that of coralline algae. Thus it was found at all localities visited in southern Queensland where patches of "lithothamnion"* occurred. In northern Queensland it was found at Bargara, where most of the rocks from about M.S.L. to M.L.W. were coated with *Lithothamnion* spp., and also at Yeppoon, where in places a "lithothamnion" band was found from M.S.L. to L.W.N. It was not encountered north of that locality on the mainland coast until Whitecliffs. There, between L.W.N. and L.W.S., a band of "lithothamnion" was found and browsing on it were specimens of *Onithochiton quercinus*.

(xi) *Zonation at Shoal Point.*—At Shoal Point, where the shore slopes gradually and the tidal range is large, the traverse made was a particularly long one. On this traverse a succession of near-vertical faces separated by boulder-strewn gullies was examined. Study of the zonation on these rock faces (see Fig. 12) has revealed some puzzling features.

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* "lithothamnion" = Unidentified encrusting calcareous algae belonging to the family Corallinaceae.

Nodilittorina pyramidalis was a dominant on rock A, which extended from just above H.W.S. to about half-way from M.H.W. to H.W.N. It was also found on rock B as low as H.W.N. but was sparsely represented. Thus this species extends much further down the beach than is the case elsewhere.

Melaraphe melanacme was not represented on rock A, although at other northern Queensland localities it was a dominant from H.W.S. to about a third of the way from M.H.W. to H.W.N. Only a few specimens were found on rock B near H.W.N. There was therefore a marked reduction in the abundance of this species and a true lower littorinid zone was lacking.

The oyster *Crassostrea amasa* was represented on rock B from H.W.N. to M.S.L. only by a few scattered specimens, yet it was a dominant between these levels at most northern Queensland localities. On the other hand it was a dominant on the same rock from just above M.S.L. to about one-third of the way from M.S.L. to L.W.N., and on rock C from half-way between H.W.N. and M.S.L. to L.W.N. On rock D it was a subdominant from about half-way between M.S.L. and L.W.N. to L.W.N. Thus the centre of abundance of the oyster occurred at a much lower level than at other northern Queensland localities.

The mussel *Brachyodontes hirsutus* and the serpulid *Pomatoleios crosslandi* were co-dominants on rock D from the top of the rock down to M.L.W. Such an association was not observed at any other locality.

Algae were dominant organisms on rock E from L.W.N. to L.W.S.

The zonation at Shoal Point was complex and difficult to interpret. However, it should be noted that environmental conditions at this locality differed markedly from those encountered elsewhere on the Queensland coast (see Appendix I).

IX. The Distribution of the Queensland Rocky Shore Fauna

(a) *The North-south Queensland Biogeographical Boundary*

Hedley (1904), after a study of Australian molluscs, recognized two faunistic provinces on the eastern Australian coast. The first, the Solanderian, he delineated as the coastal region extending from Torres Strait to Moreton Bay; but subsequently (1926) he placed the southern limit of this province at Wide Bay (about 26° S.), and defined the more southern province, the Peronian, as extending from this locality to eastern Victoria. Later authors (Iredale 1914, 1924; Clarke 1946; Dakin, Bennett, and Pope 1948; Bennett and Pope 1953) have accepted Hedley's provinces, although Bennett and Pope (1953) have defined more accurately the southern limit of the Peronian.

Figure 13 shows the percentages of species at each locality visited which are typically northern (i.e. found commonly in tropical Queensland and the islands to the north of Australia), and those which are typically southern (i.e. found commonly on the New South Wales coast and frequently on the coasts of the southern half of the Australian continent), plotted against latitude. It can be seen that at about lat. 25° 30′ S. northern forms give way rather sharply to southern forms.

Actually the region of change may be nearer to 25° S. than indicated, since at this latitude on Great Sandy Island (which as the name implies is chiefly composed of sand) there is a rocky outcrop (Indian Heads) where fishermen maintain that one can obtain for bait "cunjevoi", the colloquial name for *Pyura stolonifera*. This locality may represent the most northerly outpost of the southern forms but unfortunately its inaccessibility prevented a visit being made. Double Island Point was the most northerly locality visited which had a characteristically southern faunistic association, whilst Point Vernon, in Hervey Bay, was the most southerly locality visited which possessed a fauna with typically northern affinities. Thus the region in the vicinity of lat. 25° S. represents a faunistic boundary separating the two faunas on either side as sharply as any geographical barrier does on land, and the zonation picture on either side of the barrier is consequently different. At localities to the south of the barrier the zonation picture was essentially as outlined in Section VII(*a*) for southern Queensland, whilst at localities to the north it was essentially as described for northern Queensland (Section VII(*b*)).

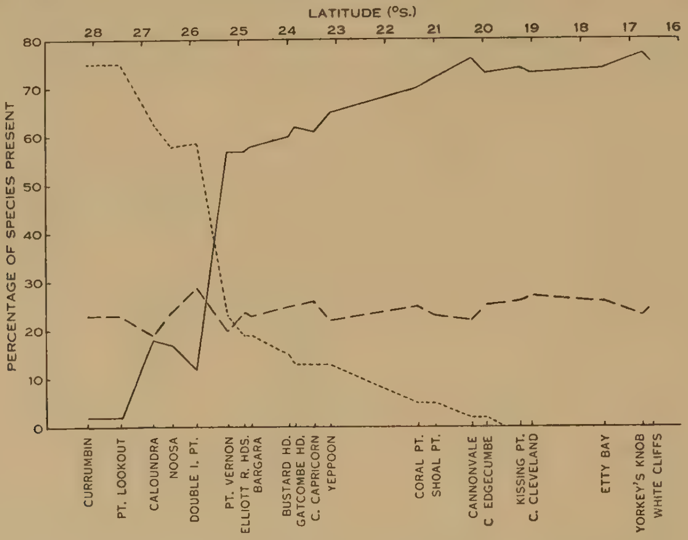

Fig. 13.—Graphical representation of percentage of "northern" and "southern" species at each locality. - - - - "Southern" species; ——— "northern" species; — — — species found throughout region of survey.

Thus the typical Peronian forms *Pyura stolonifera*, *Cellana tramoserica*, *Chthamalus antennatus*, *Melaraphe unifasciata*, *Poneroplax paeteliana*, *Melanerita melanotragus*, *Balanus nigrescens*, *Tetraclita purpurascens*, *Actinia tenebrosa*, and *Dicathais orbita* all had the northern limit of their range near Double Island Point.

Of the typical northern Queensland forms, *Monodonta labio*, *Lunella mespilus*, *Patelloida saccharina stella*, *Chthamalus malayensis*, *Perna nucleus*, *Ibla cumingii*, *Chthamalus caudatus*, *C. withersi*, *Tetraclita squamosa*, *Nerita annulata*, and *Chiazacmea heteromorpha*, all had the southern limit of their range near Point Vernon.

Moreover, at Double Island Point the southern species mentioned were typically developed, occupied their normal habitat, and occurred at their usual height relative to tidal level. This is true also of the northern forms mentioned at Point Vernon.

A few species can be considered as belonging to both the Peronian and northern Queensland faunas. Amongst these are the carnivorous thaid *Morula marginalba*, the starfish *Patiriella exigua*, the chitons *Ornithochiton quercinus* and *Liolophura gaimardi*, the barnacles *Balanus amaryllis* and *Balanus imperator*, and the littorinid *Nodilittorina pyramidalis.* The latter species was formerly known in Australia as *N. tuberculata* (Menke) but Abbott (1954) has shown this to be a Western Atlantic form. From Point Vernon northwards there was an increasing proportion of smaller, darker specimens which, when compared with specimens in the Australian Museum, were found to be identical with specimens of Philippi's *N. malaccana.* In the field, however, it was found that the species intergraded with typical specimens of *N. pyramidalis* and they were therefore considered to belong to that species. After reaching this conclusion, confirmation came from Abbott (1954) who states that he does not believe that " . . . *N. malaccana* should be recognized even as a subspecies". However, on cursory examination the northern Queensland specimens of *N. pyramidalis* certainly appear different from typical Peronian specimens.

Some typically southern species do not extend as far north as the biogeographical boundary. Thus *Galeolaria caespitosa*, *Ibla quadrivalvis*, *Catophragmus polymerus*, *Talisiphon virgulata*, *Turbo undulatus*, *Patiriella calcar*, *Notoacmea petterdi*, and *Heliocidaris erythrogramma* have not been found north of the Moreton Bay region, some 100 miles to the south of Double Island Point. It would appear therefore that there is a minor biogeographical barrier in the Moreton Bay region.

On the other hand the common northern species *Nerita costata* was not observed south of Bustard Heads, the northern barnacle *Octomeris brunnea* was not taken south of Coral Point, the northern thaid *Thais distinguenda* south of Yeppoon, the small northern littorinid *Peasiella tantilla* south of Shoal Point, nor the sea urchin *Stomopneustes variolaris* and the gastropod *Conus lividus* south of Etty Bay. Thus although there was some falling off in common species between Whitecliffs and lat. 25° S. there is apparently no such minor biogeographical barrier as exists in southern Queensland.

There was a small degree of overlapping of northern and southern forms at the biogeographical boundary. Thus *Melaraphe acutispira* ranged as far north as Bargara, *Montfortula conoidea* as far as Shoal Point, and *Patelloida latistrigata submarmorata* as far as Yeppoon. The tent-shell *Bellastrea sirius* ranged as far north as Bargara, but specimens taken north of Point Vernon were slightly different from the typical Peronian form; Iredale (personal communication) refers to them as "northern forms". Likewise, although typical *Bembicium melanostoma* extended only as far as Double Island Point, what Iredale refers to as the "northern form" of the species was found from Point Vernon to Yeppoon. Not only has this form a distinctly different facies to that possessed by the southern form but it extends over a much greater vertical range. *Austrocochlea constricta obtusa* ranged as far north as Shoal Point, but north of Point Vernon it occurred from about M.S.L.

to M.L.W. whereas in southern Queensland and New South Wales it occurred always above M.S.L.

The distribution of *Tetraclita rosea* north of Double Island Point was peculiar. It was not found at Point Vernon but small isolated patches of the barnacle occurred at Elliott River heads, Bargara, and Bustard Heads. Then it was totally absent at the localities visited north of Bustard Heads until Cannonvale and Cape Edgecumbe (over 200 miles to the north) were reached. At these localities isolated patches of the barnacle occurred chiefly between M.S.L. and L.W.N. Its occurrence at these two localities will be discussed in a subsequent paper. The barnacle was not found on the mainland coast north of Cape Edgecumbe.

As regards the southward extension of northern forms over the biogeographical boundary it should be noted that, although the typical zoning oyster of northern Queensland, *Crassostrea amasa*, occurs as such only as far as Point Vernon, it extends southwards well into New South Wales but only as scattered individuals (Iredale, personal communication). Likewise, *Zoanthus* spp. (there may be only one species comprising several colour varieties) occurred at many localities visited north of Point Vernon and, whilst not represented at Double Island Point, were found at Noosa and Caloundra. Dakin, Bennett, and Pope (1948) note the occurrence of zoanthids in two pools at Nambucca Heads in northern New South Wales. Apparently they did not meet with zoanthids elsewhere in New South Wales. The northern neritids *Nerita albicilla* and *N. polita* and the northern littorinids *Melaraphe melanacme* and *M. undulata* extended as far south as Noosa and Caloundra, although they were not observed at Double Island Point. The fact that these forms did not extend to the south of Moreton Bay lends support to the previous contention that there is a minor biogeographical boundary in this region.

Some species found on the Queensland coast appear to have a very restricted distribution. For example, *Rhyssoplax venusta* was taken only from Curtis Island and Yeppoon, *Montfortula cinerea* only from Cape Edgecumbe, *Tetraclita caerulescens* and *Tetraclita vitiata* only from Yorkey's Knob, *Chiazacmea flammea queenslandiae* only from Caloundra and Yeppoon, and *Cellana turbator* only from Caloundra and Yorkey's Knob. *Palythoa* sp. and species of soft and hard coral were also sporadic in their occurrence. Possibly further collecting, particularly in the continental islands, will throw light on the distribution of some of the forms.

(*b*) *The Moreton Bay Region*

The present study began on the foreshores of Moreton Bay, but it was soon realized that the fauna differed from that found on the shoreline to the north and south of this region. Within Moreton Bay a curious mixture of Great Barrier Reef forms, northern Queensland mainland forms, Peronian forms, and widely ranging Indo-Pacific forms was found. However, the fauna of the bay is predominantly northern in its affinities (Endean 1953; Stephenson 1954; Stephenson and McNeill 1955) despite the fact that on the seaward sides of the islands enclosing the bay southern forms predominate, as at Point Lookout and Cape Moreton.

Traverses were made at Dunwich on the eastern side of Moreton Bay and at Scarborough on the mainland on the western side. At Dunwich, *Nodilittorina* *pyramidalis*, *Melaraphe unifasciata*, *Bembicium melanostoma*, *Austrocochlea constricta obtusa*, *Morula marginalba*, *Liolophura gaimardi*, and *Pyura stolonifera* were found. None of the other common southern Queensland rocky ocean shore forms was observed and accordingly the zonation pattern was different. Thus at Dunwich there was a littorinid zone above M.H.W. and a *Bembicium* zone from M.H.W. to M.S.L. From M.S.L. to M.L.W. the commercial oyster *Crassostrea commercialis* plastered the rocks and from M.L.W. to L.W.S. there was a zone of the mussel *Brachyodontes hirsutus*. Below L.W.S. soft corals and *Sargassum* spp. were intermingled.

At Scarborough, of the species found commonly on the rocky ocean shores of southern Queensland only *Melaraphe unifasciata*, *M. acutispira*, *Austrocochlea constricta obtusa*, *Morula marginalba*, and *Liolophura gaimardi* were found. However, a few specimens of the northern littorinid *Melaraphe melanacme* were observed, the northern barnacle *Balanus* sp. nov. I and the northern gastropod *Planaxis sulcatus* were common, and the northern serpulid *Pomatoleios crosslandi* formed a zone from just below M.S.L. almost to L.W.S., yet this species was not observed on the exposed coast until Point Vernon over a hundred miles to the north was reached. Other animals commonly encountered were *Bembicium keilmanseggi*, *Brachyodontes hirsutus*, and the hydroid *Dynamena crisioides*.

As mentioned previously, the temperature range in Moreton Bay is greater than on the seaward side of the islands in Moreton Bay. Temperature and chlorinity data are available for the oyster lease near Dunwich (Rochford 1953*b*). In 1952 the maximum temperature recorded was 29·7° C and the minimum 15·2°. The maximum chlorinity recorded was 20·52‰ and the minimum 18·84‰. Thus there is a relatively large annual temperature range and this may be responsible for the absence of many common forms found normally on the shores of southern Queensland. The reduction in salinity is possibly no greater than would be normally encountered on many parts of the southern Queensland coast after heavy rain and probably is not a major factor in this connexion. Of greater importance, perhaps, is the reduction in wave action, for it is only occasionally that wave action of any magnitude is experienced at Dunwich and this may be of importance with respect to the absence of typical southern Queensland coastal barnacles such as *Tetraclita rosea*, *T. purpurascens*, and *Chthamalus antennatus*.

Scarborough is only a few miles from Toorbul Point to the north and Pine River outlet to the south. Temperature and salinity data for the years 1950-1952 are available for these two localities (Rochford 1952, 1953*a*, 1953*b*). The temperature range seems to be between 15·5° and 25·0° C, although it is probable because of the long periods that elapsed between successive temperature recordings that the maximum and minimum temperatures were not recorded. A similar criticism might be levelled against the salinity data recorded, but this is of interest as it gives an indication of the salinity ranges to be expected at these localities. The minimum chlorinity recorded at Toorbul Point was 3·97‰ and the maximum 17·85‰, whilst at Pine River outlet the values were 7‰ and 17·85‰ respectively. Thus the salinity range at Scarborough must have been very great also, and this was reflected in the presence of the estuarine species *Bembicium keilmanseggi*. It is of importance, therefore, to note that the northern serpulid *Pomatoleios crosslandi*, the northern gastropod *Planaxis sulcatus*, and to a lesser extent the northern littorinid *Melaraphe melanacme* can withstand great changes in salinity. *Austrocochlea constricta obtusa* was also common, and it is noteworthy that this was one of the few southern gastropods that extended its range past Point Vernon. A small brown anemone found at Scarborough also appeared to be identical with the brown anemone found in northern Queensland.

Caloundra is situated on the coast near the northern entrance to Moreton Bay and is sheltered from the prevailing south-east trades by Moreton and Stradbroke Islands. Although most of the rocky shore organisms found at Currumbin were represented at Caloundra (with the notable exception of *Galeolaria caespitosa*) there was a strong northern element in the fauna generally. Thus corals (*Favia speciosa*, *Leptastrea purpurea*, *Favites abdita*, and *Acropora* spp.) were present in pools. Additional species were present on rocks well below L.W.S., where they have been seen by spear fishermen. Some have been washed up, including *Pocillopora damicornis*, *Turbinaria peltata*, *Goniopora lobata*, and *Acropora* spp. Soft corals (*Xenia* sp. and *Alcyonium* sp.) were also represented and zoanthids were found commonly in crevices. Tropical molluscs, viz. *Nerita albicilla*, *N. polita*, *Planaxis sulcatus*, *Conomurex luhuanus*, and cowries, were well represented, as were tropical echinoderms, viz. *Holothuria atra*, *H. leucospilota*, *Discucumaria africana*, and *Echinometra mathaei*.

Thus the fauna of the Moreton Bay-Caloundra region differs from that of the fauna on rocky shores in southern Queensland generally. Hedley (1925*c*) noted 15 species of coral in Moreton Bay and regarded this assemblage as a "southern outlier of the coral fauna". Wells's (1955) report on the Moreton Bay corals, both alive and dead, confirmed this. Endean (1953, p. 58) noted that the Moreton Bay echinoderm fauna is a rich yet isolated one, and that "Port Curtis over two hundred miles to the north is the nearest locality with a fauna somewhat akin to it".

Bennett and Pope (1953) instance the occurrence of corals in Moreton Bay as support for the contention, first advanced by Allee (1932), that species representative of warmer waters can extend their geographical ranges into colder latitudes by living in shallow inlets where the summer temperatures are greater. It should be noted that although the summer temperatures over the shallow flats in Moreton Bay are warmer than the outside sea temperatures in summer, they are far colder in winter. Presumably the summer temperatures are the critical ones.

X. Discussion

In Queensland, as in other parts of the world, the intertidal rocky shore can be divided into a series of zones, each possessing a characteristic assemblage of organisms. One of the major problems of seashore ecology is to account for these zones. Stephenson and his colleagues (Stephenson 1939, 1944, 1948) have approached the problem by investigating the ecology of seashore animals over a great extent of coast. This approach has the advantage that varying conditions are encountered naturally in the field and the response of these animals to a whole complex of changing conditions can be observed. It has, however, the obvious disadvantages that the interpretation of results is largely subjective and the precision of laboratory experiments is lacking.

In the present work, nevertheless, the approach of Stephenson and his colleagues was followed, for similar reasons. Firstly, ecological data on the intertidal animals of Queensland shores were practically negligible. The initial task therefore was to obtain information on the animals present, their relative abundance, their geographical range in Queensland, and their normal habitat. This information is given in Table 1. Secondly, little was known about zonation patterns in Queensland or the effect of local variations in environmental factors on these patterns. The information gleaned in the necessarily short time available for investigation is incorporated where relevant in this paper. Thirdly, little was known on the effects of gross environmental changes related to latitude. Information secured on this aspect is discussed in Section IX. Analysis of all these data has thrown much light on faunistic composition and zonation on Queensland shores and is discussed below.

(*a*) *Southern Queensland Zonation*

It is shown above that, despite some important differences, the faunistic composition and zonation are basically similar to those of New South Wales as described by Dakin, Bennett, and Pope (1948).

Splash and spray from breaking waves had little apparent effect on the position of the upper levels of the algal-ascidian zone, which was found at constant height above L.W.S. and was sharply demarcated, particularly on vertical faces. On an average the upper level of the algal-ascidian zone would be exposed for approximately 15 min per tide, but under calm conditions at low-water spring tides the periods of exposure are much greater.

Specimens of the ascidian *Pyura stolonifera* have been kept in the laboratory, out of water, for as long as 16 hr. On replacing in sea-water they soon behaved normally, which possibly suggests that periodical exposure of the adults to the atmosphere is not particularly critical. Moreover, the ascidians near the upper level of their zone were just as well developed as those occurring at lower levels, and of comparable size. The key to the reason for the sharp upper limit of the ascidian might well lie in a study of its larval stages.

As regards Algae, Dakin, Bennett, and Pope (1948) mention the occasional coincidence of low-water spring tides with exceptionally calm conditions as being of possible significance in restricting the upward extension of the algal zone, and such occurrences may be of importance in southern Queensland also.

The upper limit of the serpulid *Galeolaria caespitosa* occurred just below M.S.L., corresponding to an average exposure per tide of about 3 hr. Occasionally patches of this species were found above the main zone, but these occurred in surge channels between rocks which drained slowly because of the run-off received from other rocks in the vicinity. These observations lend support to the contention of Dakin, Bennett, and Pope (1948, p. 214) that the species is "adapted for a fairly prolonged period of submergence under water" and that on occasions when there is no swell "the limiting factor for the upper cut-off could well be tidal level". There is, however, no indication of how factors associated with tidal level prevent *G. caespitosa* from invading higher levels.

The lower level of the *Galeolaria* zone was also sharply demarcated. It would seem that this was due to the presence of the algal-ascidian zone, for it was noted that the ascidian, if present, overgrew any serpulid tubes that extended below this point and that in places where the ascidian was absent the presence of an algal mat seemed to be inimical to the development of the serpulid.

Rarely were the upper levels of the barnacle zones as sharply defined as those of the algal-ascidian and *Galeolaria* zones. Apparently the explanation of this lies in the fact that rock configuration in the upper intertidal area is such (see Section VII) that certain areas receive more splash than others. In regions which received excessive splash, specimens of *Tetraclita rosea* were found well above H.W.N., and specimens of *Chthamalus antennatus* as high as H.W.S. At the same time the *Chthamalus* zone was better developed in semi-sheltered than in more exposed situations. Possibly competition by *T. rosea* was responsible for this. On the sheltered traverse at Point Lookout, for example, where the population of *T. rosea* was markedly reduced in numbers, *C. antennatus* extended down the beach as low as M.S.L.

An especially interesting observation was the downward extension of the *Tetraclita* zone to fill the region vacated by the *Galeolaria* zone when this disappeared from the intertidal scene to the north of Point Lookout. Apparently the lower limit of the *Tetraclita* zone is normally determined by the upper limit of the *Galeolaria* zone. At localities where the *Galeolaria* zone was well developed the encrusting tubes of this serpulid were so dense and intertwined that little substratum was exposed for the attachment of other forms.

The upper limit of the lower littorinid zone seemed to be determined by tidal factors and was always at the same effective tidal level. The position of the lower limit varied somewhat and was influenced by the degree of wave action normally occurring. At localities where wave action was slight, as on the sheltered traverses at Point Lookout and Noosa, *Melaraphe unifasciata* extended down the beach to a much lower level than usual.

The upper limit of the upper littorinid zone at any locality was directly related to the amount of wind-blown spray normally received in the supralittoral region: the greater the amount of spray the higher the littorinid occurred. On the other hand the lower limit of the zone coincided with the position of effective H.W.S. *Nodilittorina pyramidalis* was rarely found in a position where it could be completely covered with water.

(*b*) *Northern Queensland Zonation*

Although in northern Queensland no ascidian was associated with the algal zone, the upper limit of this zone occurred at a similar level, relative to effective tidal height, to that of the algal-ascidian zone in southern Queensland.

The upper limit of the *Tetraclita* zone, which replaced the southern Queensland *Galeolaria* zone, was affected by the amount of surge and splash at any locality.

Clumps of barnacles were observed often above the main zone in situations which, because of idiosyncrasies of shore profile in the region, received more surge and splash from waves. The lower limit of the zone seemed to be determined by the upper limit of the algal mat.

An oyster zone occupied the region between H.W.N. and M.S.L. in northern Queensland and gave a most characteristic facies to the zonation picture. The occurrence of a bivalve-dominated zone, however, is not unique, as a similar zone occurs in South Africa (Stephenson 1948) and in Malaya (Purchon and Enoch 1954). The upper limit of the oyster zone was always sharply demarcated and seemed to be determined primarily by tidal factors. On the other hand the lower limit frequently was not sharply delineated and isolated specimens were found as low as L.W.N.

Above the oyster zone a *Chthamalus* zone was found. Its upper limit was influenced by splash, as was that of its counterpart in southern Queensland, but was found generally near M.H.W. The lower limit was variable, and on vertical and near-vertical faces the barnacle extended down sometimes as a dense sheet, to below M.S.L.

The upper limit of the lower littorinid zone was found at a height relative to tidal level similar to that of its southern counterpart. Its lower limit was also variable but the variation was not obviously related to wave action as was the case in southern Queensland.

As in southern Queensland, *Nodilittorina pyramidalis* was found above H.W.S. in the spray zone.

In the main, browsing gastropods were commoner in the region from H.W.N. to L.W.N. in northern Queensland than they were in southern Queensland. This was probably due to the greater accumulation of rubble in this region in northern Queensland owing to less severe wave action than in southern Queensland.

From Cannonvale northwards the tidal range is similar to that in southern Queensland, but because of the virtual absence of wave surge effective tidal heights are only slightly higher than predicted heights. Consequently the vertical range of each species at any locality in this region was usually much less than that of the corresponding zone at southern Queensland localities. In the Shoal Point region the tidal range is over twice as great as in southern Queensland, and at this locality there occurred a remarkable lowering of the littorinid and oyster zones. The reasons for this lowering are not known.

Another puzzling phenomenon was the alteration in the vertical ranges of *Austrocochlea constricta obtusa* and *Bembicium melanostoma* north of lat. 25° S. In southern Queensland these species were found most commonly in the region from H.W.N. to M.H.W. At Bargara, however, *Austrocochlea constricta obtusa* was found from M.S.L. to M.L.W. and *Bembicium melanostoma* from H.W.N. to below M.S.L.

(c) *Critical Tidal Levels*

Many workers (Colman 1933; Fischer-Piette 1936; Stephenson 1941; Chapman 1943; Doty 1946; Evans 1947*a*, 1947*b*; Beveridge and Chapman 1950; Dellow 1950; Knox 1953) have discussed the relationship between the vertical ranges of littoral animals and certain so-called critical tidal levels. Evans (1947*b*), after a study of zonation near Cardigan Bay, Wales, and of several localities near Plymouth, has made some generalizations on zonation which Knox (1953) has shown to be equally applicable to zonation at Taylor's Mistake, New Zealand. It is of interest to ascertain whether these generalizations apply to zonation in Queensland. Unfortunately there is a lack of precise tidal data for northern Queensland localities with which to compare tidal data derived from field observations. The only comprehensive data available pertains to certain ports and harbours situated in estuaries or some distance up navigable rivers.

Consequently the subsequent discussion refers to zonation in southern Queensland only.

The first generalization of Evans concerns the region between M.L.W.N. and M.L.W.S., which he regards as critical in the sense that the majority of intertidal plants and animals reach their lower limits in this region. In southern Queensland only five of the 27 common animal species shown in Figure 6 have their lower limits between M.L.W.N. and M.L.W.S. Consequently in southern Queensland this region cannot be considered a critical one.

Evans's second generalization refers to the observation that although certain sublittoral species penetrate into the littoral region they extend only as high as the vicinity of M.L.W.N. Of the common southern Queensland animals eight could conceivably be placed in this category, viz. *Pyura stolonifera*, *Balanus nigrescens*, *B. imperator*, *Patiriella calcar*, *Poneroplax paeteliana*, *Turbo undulatus*, *Montfortula conoidea*, and *Dicathais orbita*. It is doubtful, however, in the absence of detailed observations below L.W.S. whether all of these animals are truly sublittoral. In fact, observations over a period of years suggest that *Balanus nigrescens*, *Dicathais orbita*, and probably *Montfortula conoidea* and *Turbo undulatus* are more abundant just above L.W.S. than below it.

The third generalization, that levels between M.H.W.S. and E.H.W.N. are critical for a large number of species in that many reach their upper limits in this region, does seem to apply to southern Queensland. Eleven common southern Queensland species have their upper limits in this region.

The applicability of Evans's fourth generalization, which refers to the observation that the least critical levels on the shore are between E.L.W.N. and E.H.W.N., is debatable. In southern Queensland *Galeolaria caespitosa*, *Siphonaria marza*, and *Patelloida submarmorata* have their upper limits, whilst *Tetraclita rosea* and *Catophragmus polymerus* usually have their lower limits, in this region. In addition, at sheltered localities *Chthamalus antennatus*, *Melaraphe unifasciata*, *Austrocochlea constricta obtusa*, and *Bembicium melanostoma* frequently extend as low as the vicinity of M.S.L.

It would seem, therefore, that Evans's generalizations are only partially applicable to the zonation of the southern Queensland intertidal fauna. However, it should be noted that in southern Queensland three of the chief zoning animals, *Pyura stolonifera*, *Galeolaria caespitosa*, and *Tetraclita rosea*, are usually so abundant that little substratum is available for use by other animals. In particular, the encrusting tubes of *G. caespitosa* seem to act as a barrier both to the upward extension of animals found commonly below L.W.N. and to the downward extension of animals found above M.S.L. The well-developed algal zones in Britain (Colman 1933; Kitching 1935; Evans 1947*b*) occurring between L.W.N. and M.S.L. do not appear to act as equivalent barriers.

Doty (1946, p. 320) has pointed out that in Oregon and northern California, tides are such that at certain levels on the shore "there are sudden increases or decreases in the duration of exposure to the various factors in the environment . . ." The levels at which these sudden changes in the length of exposure occur he has shown to be closely correlated with the breaks between the major algal zones and with the upward or downward limits of distribution of those species not extending over the whole breadth of a zone.

In southern Queensland the tidal curves are somewhat similar to those found in the region investigated by Doty. As can be seen from Figure 8, the difference in the rate of change of percentage exposure to air, from one level to another, is most pronounced at approximately M.H.W. and M.L.W. It is noteworthy that many species have their upper limits at M.H.W. On the other hand it is doubtful whether any of the common species normally have either their upper or lower limits at M.L.W. In fact the sharp upper limits of the algal-ascidian and *Galeolaria* zones occur at levels where no marked variation in the rate of change of percentage exposure to the air is in evidence.

(*d*) *The North-south Queensland Zoogeographical Boundary*

The present work confirms the view of the earlier systematists (see Section IX) that a zoogeographical boundary occurs near the southern tip of the Great Barrier Reef and fixes its position at about lat. 25° S. At Double Island Point typical southern forms flourish, and only one typical northern form is found yet about 30 miles to the north-west; at Point Vernon northern forms abound and very few southern forms occur. This switch-over must be as dramatic as can be found anywhere in the world's seashores.

Since temperature varies more or less regularly with latitude on the eastern Queensland coast, there being no marked temperature change in the region of lat. 25° S., the causes of this switch-over must be sought elsewhere.

Northern Queensland waters differ markedly from those of southern Queensland with respect to wave action. At many localities on the coastline of the northern Queensland mainland, the offshore water resembles that of a lake and true surf is found only in the vicinity of some of the more exposed headlands. The chief reason for this is that the coastline north of lat. 25° S. is protected, firstly, by the Great Barrier Reef, and secondly, by innumerable small reefs and mainland islands within the lagoon. In addition, north of lat. 25° S. the coastline swings to the north-west and consists mainly of a succession of long sweeping bays, each ending to the south in a northerly directed rocky headland, whilst the prevailing winds are the south-east trades.

Strong indications that lack of wave action is responsible for the sharp decline in numbers of the barnacle *Tetraclita rosea* on the mainland north of lat. 25° S. were afforded by the following observations. Study of the feeding behaviour of *T. rosea* at Currumbin revealed that the opercular valves remained closed whilst each wave broke and surged up the rock face. As each wave receded the barnacle protruded its cirri to form a net and thereby trapped small organisms. Lack of wave surge would undoubtedly militate against the efficiency of such a mode of feeding. It was, therefore, of interest to note that at Elliot River heads, one of the few localities to the north of lat. 25° S. where this species occurred (see Section IX), specimens were found only near the apex of a sloping funnel-shaped gutter in the rocks which tended to amplify the small waves, causing them to surge upwards over the barnacles at the apex. In this respect too it was perhaps significant that the common large northern Queensland barnacle, *Tetraclita squamosa*, feeds by a clutching action of its thoracic legs and was found at a much lower level than its southern counterpart.

Observations were also made which point to lack of wave action as being directly or indirectly responsible for the disappearance of *Melaraphe unifasciata* and its replacement by *M. melanacme* in northern Queensland waters. In southern Queensland *M. melanacme* was not observed at the exposed locality of Double Island Point, where *M. unifasciata* was a dominant. However, the two species occurred side by side at Noosa, where exposed and sheltered traverses were made. On the exposed traverse *M. unifasciata* was a dominant from just above M.H.W. to H.W.N. whilst *M. melanacme* was only sparsely represented. On a sheltered traverse about 300 yards away the two were co-dominant. On the other hand at Point Vernon, a very sheltered locality, and the next visited to the north of Double Island Point, *M. melanacme* was a dominant and *M. unifasciata* was not observed. However, in June 1952 four adult specimens of *M. unifasciata* were found at Elliot River heads, the next locality to the north. It would appear that *M. unifasciata* can survive in the region immediately north of latitude 25° S. but cannot compete with *M. melanacme*, and the reverse is true south of lat. 25° S. It would appear that the extent of wave action is the main factor involved.

It is also conceivable that other southern Queensland species, such as *Pyura stolonifera* and *Balanus nigrescens*, which seem to exhibit a preference for turbulent waters were not observed in the coastal waters north of lat. 25° S. because of reduced wave action. However, not a single specimen of either species was observed north of lat. 25° S. although both were abundant a short distance to the south at Double Island Point. It is possible that other factors such as turbidity or salinity might be of importance.

On the other hand northern Queensland species either cannot tolerate heavy wave action such as prevails at Double Island Point, or cannot compete with southern Queensland forms which are better adapted for such conditions. Some northern forms are found as far south as Moreton Bay, but in most cases only in sheltered localities. Here too, other factors probably enter into the picture.

Thus evidence has been produced that the water bathing the coast at many northern Queensland localities is, at least periodically, much less saline than in southern Queensland. It is significant that such species as *Pomatoleios crosslandi*, *Balanus* sp. nov. I, *Planaxis sulcatus*, *Liolophura gaimardi*, *Austrocochlea constricta obtusa*, and *Morula marginalba*, which are found commonly on the northern Queensland coast, were present at Scarborough in Moreton Bay where the salinity is frequently very low. *Liolophura gaimardi*, *Austrocochlea obtusa*, and *Morula marginalba* are also found commonly in southern Queensland, but of all the other southern Queensland forms only *Melaraphe unifasciata* and *Melaraphe acutispira* were represented at Scarborough.

It is difficult to account for the disappearance north of the Moreton Bay region of *Galeolaria caespitosa*, *Catophragmus polymerus*, *Turbo undulatus*, *Dinassovica militaris*, and the typical Peronian echinoderms *Patiriella calcar* and *Heliocidaris erythrogramma*. Indeed, there seems to be a dearth of intertidal echinoderms between Caloundra and Point Vernon (Endean 1953). A factor of possible importance is that during winter and for much of the autumn and spring (see Section IV(*g*)) a branch of the warm southern equatorial current impinges on the shore in the vicinity of Great Sandy Island, where it is deflected to the south-east. Frequently, however, eddies from this set northward along the coast north of Cape Moreton. This could give rise to short-term temperature fluctuations in this region but no data are available for such fluctuations. Recorded temperatures between Moreton Bay and Double Island Point show merely a seasonal temperature range from about 19·5° C in August to about 25·5° in February.

The species mentioned above were not represented at Dunwich on the eastern side of Moreton Bay. Here the salinity varies only slightly, but wave action is greatly reduced compared with that on the unprotected coast. Reduction of wave action possibly accounts for the absence of coastal barnacles at Dunwich but should not affect *Galeolaria caespitosa*, which is most abundant in partially sheltered situations. The temperature at Dunwich fluctuates seasonally between the extremes of 15° and 30° C, which suggests that temperature fluctuations might be the chief reason for the absence of *Galeolaria caespitosa*.

It is of interest to note that the typical southern species *Melaraphe unifasciata*, *Bembicium melanostoma*, *Austrocochlea constricta obtusa*, and *Pyura stolonifera* were found at Dunwich. This would indicate that these species can withstand higher sea temperatures than those normally occurring at Double Island Point.

The absence from Dunwich of *Pomatoleios crosslandi*, which occurred at Scarborough (on the western side of the bay) where the average minimum temperature and average extent of wave action seem to be similar to those at Dunwich, once again indicates that this species is adapted to a lower salinity than that normally found on the southern Queensland coast.

(*e*) *Incidence of Coral on the Queensland Mainland Coast*

Because of the proximity of the Great Barrier Reef to the northern Queensland mainland it would be expected that common reef animals and particularly coral growths would be encountered frequently on the mainland. Such has not proved to be the case. Fairbridge (1950) commented that "in the Great Barrier Reef region the paucity of fringing reefs is striking in view of the variety and abundance of reefs further off shore". In the present investigation the only northern localities where coral entered the picture at all were Cannonvale, Shoal Point, Coral Point, and Cape Edgecumbe.

Porites lutea was the commonest coral encountered on traverses, but this was far more abundant in nearby pools. The remainder of the corals also seemed to be typically pool-dwellers, extending only occasionally to exposed rock surfaces. These included *Goniastrea pectinata*, *Acropora variabilis*, *Favia speciosa*, *Favites abdita*, *Cyphastrea serailia*, *Leptastrea purpurea*, *Psammocera vaughani*, *Turbinaria peltata*, and *T. danae*. Some of these occurred as far south as Caloundra, and they are mostly common and physiologically resistant species which attain their maximum development on reef flats of the Great Barrier Reef.

Turbidity as a factor primarily responsible for the paucity of corals on the mainland can be dismissed, because the water at the localities where coral was found was just as turbid as at other localities where coral was absent. However, salinity may be of importance, since the mainland localities where coral was found are removed from the influence of large river systems.

At Coral Point a number of dead *Acropora* colonies were observed in pools. Mr. J. A. Dent of Mackay has given an account of the deluge in January 1951 which was responsible for the death of this coral. He writes "about sixty inches of rain fell over about three days. There were some particularly heavy downpours when the registration would be well over an inch an hour . . . The fresh water run off was phenomenal . . . From the amount of damage in evidence I would hazard a guess that all creatures at all sensitive to the presence of fresh water perished. In some of the pebbly coves they were knee deep . . . in some sections sea slugs and sea cucumbers predominated, in others it was muttonfish whilst in others it was octopi . . . the coral was literally blanketed with silt . . . Weeks after the dead coral was covered with a layer of fine mud".

Hedley (1925*a*) has produced evidence which pointed to flood rains associated with the cyclone of 1918 being responsible for the destruction of the coral reef on Stone Island (near Cape Edgecumbe), which was much photographed by Saville-Kent. Rainford (1925) attributed the destruction of the coral reefs in the vicinity of Whitsunday Island to a similar cause. It would seem, therefore, that heavy cyclonic rains may be the major factor in preventing coral and its associated fauna from establishing themselves on the mainland to any extent.

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Appendix I

Notes on the Localities Investigated

In the following notes the latitudes and longitudes of the various localities are given to the nearest minute. The degree of wave action listed for most localities in southern Queensland is based on knowledge gleaned as a result of repeated visits over the last 5 years. In northern Queensland estimates of the degree of wave action are based on observation during the period of investigation and on information obtained from local fishermen, lighthouse keepers, etc.

(1) *Currumbin.*—Lat. 28° 8′ S., long. 153° 29′ E. Meranleigh metamorphic. *Traverse* 1.—Facing ENE.; pitted and gullied rocky outcrop at northern end of Currumbin beach; isolated boulders in sand at foot of traverse; piled boulders

above H.W.S.; slope about 45°; exposed; wave action moderate; frequently oceanic swell; water clear.
Traverse 2.—Facing NE.; bare rock with isolated boulders in sand at base of traverse; overall slope about 35°, exposed; wave action moderate; frequently oceanic swell; water clear.
Traverse 3.—Facing ESE.; rocky platform about 120 yards offshore; just awash at M.H.W.S.; exposed; wave action moderate; frequently oceanic swell; water clear.

(2) *Dunwich.*—Lat. 27° 31′ S., long. 153° 24′ E. Sandstone.
Traverse 1.—Facing W.; rocky outcrop on point west of township; shingle near H.W.S.; slope about 10°; exposed; wave action very slight except when winds with westerly component blowing; water sometimes turbid.

(3) *Point Lookout.*—Lat. 27° 26′ S., long 153° 33′ E. Rhyolite.
Traverse 1.—Facing ESE.; headland near camping reserve; rocky cliffs with a few ledges, gutters, and gullies; slope about 65°; exposed; wave action severe; usually oceanic swell; water clear. (Surge is so pronounced at this locality that animals below H.W.N. could only be observed safely by using binoculars.)
Traverse 2.—Facing NE.; about 600 yards north of traverse 1; small rock platform near L.W.N. backed by large rocky outcrop; slope of outcrop about 80°; semi-exposed; wave action moderate; usually some oceanic swell; water clear.
Traverse 3.—Facing NW.; near traverse 2; bare rock platform, pitted surface, slope about 15°, sheltered; wave action slight; water clear.

(4) *Scarborough.*—Lat. 27° 12′ S., long. 153° 7′ E. Lateritized basalt.
Traverse 1.—Facing E.; pitted and creviced rocky outcrops separated by patches of shingle and sand, overall slope about 10°; sheltered; wave action slight, water turbid.

(5) *Cape Moreton.*—Lat. 27° 2′ S., long. 153° 28′ E. Coal seams with interbedded rhyolite.
Traverse 1.—Facing ESE.; bare rocky outcrop with rounded contours and occasional gullies; slope about 30°; exposed; wave action moderate, sometimes severe; usually some oceanic swell; water clear.

(6) *Caloundra.*—Lat. 26° 48′ S., long. 138° 9′ E. Sandstone.
Traverse 1.—Facing E.; northern end of beach; rock platform with pitted surface from M.H.W.S. to M.L.W.N.; piled boulders above intertidal region; below L.W.N. numerous piled boulders; occasional drainage channels and rocky pools; overall slope about 10°; exposed; wave action slight to moderate; water clear.
Traverse 2.—Facing NNE.; bare rock platform; slope about 10°; wave action slight to moderate; sometimes oceanic swell; water clear.

(7) *Noosa Heads.*—Lat. 26° 23′ S., long. 153° 7′ E. Quartzite.
Traverse 1.—Facing SE.; southern end of headland; rocky outcrop stepped from M.L.W. to H.W.S.; isolated rocks at part of traverse; overall slope about 20°; above H.W.S. stepped cliff face with overall slope of about 70°, rock pitted and an occasional tidal pool; exposed; wave action moderate; sometimes severe; usually oceanic swell; water clear.

Traverse 2.—Facing E.; piled rounded stones in long gully at right angles to strand line; gully walled by vertical rock faces about 12 ft high; overall slope of floor of gully about 25°; sheltered; wave action slight; water clear.

(8) *Double Island Point.*—Lat. 25° 56′ S., long 153° 11′ E. Basalt.
Traverse 1.—Facing SSE., pitted rocky outcrop; deep channels and gutters; slope about 45° from L.W.S. to H.W.S., intertidal region backed by steep cliffs; exposed; wave action moderate, occasionally severe; usually oceanic swell; water clear.

(9) *Point Vernon.*—Lat. 25° 15′ S., long. 153° 49′ E. Burrum coal measures.
Traverse 1.—Facing NNW.; jagged rock stepped from L.W.S. to H.W.S.; numerous long gullies at right angles to shore; slope about 20°; semi-exposed; wave action negligible except when strong north-easterly winds blowing; water turbid.

(10) *Elliot River Heads.*—Lat. 24° 55′ S., long. 152° 30′ E. Basalt.
Traverse 1.—Facing E.; about three-quarters of a mile N. of estuary; creviced, pitted rock; slope about 50° from L.W.S. to just above H.W.S., then the rock is stepped back to top of low cliffs; exposed; wave action slight; water turbid.
Traverse 2.—Facing ENE.; boulders of various sizes piled in long funnel between rocky walls about 14 ft high; slope about 20°; sheltered; wave action very slight; water turbid.

(11) *Bargara.*—Lat. 24° 49′ S., long. 152° 28′ E. Basalt.
Traverse 1.—Facing NE.; small rounded boulders resting on rubble and occasional sand patches; slope about 10°; semi-exposed; wave action slight; water turbid.
Traverse 2.—Facing NE.; large piled boulders; pitted surface; many overhangs and crevices, slope 20-25°; exposed; wave action slight; water turbid.

(12) *Clewes Point, Bustard Heads.*—Lat. 24° 0′ S., long. 151° 44′ E. Granite with basalt inserts.
Traverse 1.—Facing N.; smooth rounded granite outcrop with inserts of rough-surfaced basalt; overhangs, crevices, and occasionally piled boulders; overall slope about 30°; semi-exposed; wave action slight, occasionally oceanic swell; water turbid.

(13) *Gatcombe Head.*—Lat. 23° 53′ S., long. 151° 22′ E. Gneiss.
Traverse 1.—Facing SW.; piled rounded boulders from M.S.L. to L.W.N.; rocky outcrop from M.S.L. upwards; overall slope about 20°; sheltered; wave action very slight; water muddy. (It is suspected that semi-estuarine conditions prevail at times.)

(14) *Cape Capricorn.*—Lat. 23° 29′ S., long. 151° 14′ E. Metamorphic.
Traverse 1.—Facing NW.; jagged, deeply gullied rocky outcrop, slope about 65°; semi-exposed; wave action slight, occasionally oceanic swell; water turbid.

(15) *Yeppoon.*—Lat. 23° 9′ S., long. 150° 46′ E. Meranleigh greywacke.
Traverse 1.—Facing E.; jagged, pitted rock, serrated outcrops separated by deep gullies; intertidal area backed by high cliffs; overall slope of intertidal region about 15°, slope of cliffed region about 80°; exposed; wave action slight to moderate, occasionally oceanic swell; water very turbid.
Traverse 2.—Facing ENE.; jagged rocky outcrops separated by patches of grit and sand from M.S.L. to L.W.N.; above M.S.L. rocks channelled and fractured;

overall slope about 30°; semi-exposed; wave action slight; occasionally oceanic swell; water very turbid.
Traverse 3.—Facing ENE.; in intertidal region rocky outcrops with vertical faces fronting sea; deep gullies between successive outcrops; overall slope about 10°; steep cliffs above H.W.S.; slope of these about 80°; semi-exposed; wave action slight; occasionally oceanic swell; water very turbid.
Traverse 4.—Facing NE.; numerous small rounded boulders resting on rubble, grit, and sand; slope about 15°; sheltered; wave action very slight; water muddy.

(16) *Coral Point.*—Lat. 21° 22′ S., long. 149° 19′ E. Granite.
Traverse 1.—Facing NE.; smooth, deeply gullied outcrops; gullies parallel to shoreline and hence a succession of vertical and near-vertical faces fronting sea; upper gullies filled with rubble; exposed; wave action slight; water turbid.

(17) *Shoal Point.*—Lat. 21° S., long. 149° 9′ E. Basalt.
Traverse 1.—Facing E.; jagged rocky outcrops with long axes parallel to shoreline and backed by sand from H.W.N. upwards; successive outcrops separated by gullies filled with small rounded boulders; overall slope about 10°; exposed but whole area protected by small islands and at low tide by sand and mud banks; wave action negligible except at high tide when it is slight; water very turbid. (Owing to large tidal range in this region the traverse was a long one—over 100 yards.)

(18) *Cannonvale.*—Lat. 20° 16′ S., long. 148° 43′ E. Granite.
Traverse 1.—Facing NNW.; large piled and pitted boulders; numerous crevices and shaded overhangs; boulders at foot of traverse in shallow water; about 30° slope; semi-exposed but whole area on lee side of northerly projecting headland; wave action almost negligible; water very turbid. (Both coral reefs and *Zostera* flats in vicinity.)

(19) *Pigeon Island.*—Lat. 20° 16′ S., long. 148° 42′ E. Basalt.
Traverse 1.—Facing NE.; jagged surface; occasional gullies; 40° slope; semi-exposed but protected by northerly projecting land mass; wave action negligible; water very turbid. (Island is a tidal island connected on western side by shallow *Zostera* flats to mainland.)

(20) *Cape Edgecumbe.*—Lat. 19° 59′ S., long. 148° 16′ E. Red granite.
Traverse 1.—Facing SE.; smooth pitted surface; numerous piled boulders in water at foot of traverse and on either side; about 30° slope; exposed but whole southern side of cape protected to large extent by Cape Gloucester on easterly side of bay; wave action slight; coral reefs in vicinity; water turbid.

(21) *Cape Cleveland.*—Lat. 19° 1′ S., long. 147° 1′ E. Rhyolites and porphyries.
Traverse 1.—Facing NE.; piled boulders from L.W.S. to M.S.L.; M.S.L. to H.W.S. stepped; slope of lower half about 40°, upper half with vertical and horizontal faces; semi-exposed; wave action slight, as traverse was on sheltered side of headland; water turbid.

(22) *Kissing Point.*—Lat. 19° 14′ S., long. 146° 48′ E. Red granite.
Traverse 1.—Facing ENE.; smooth pitted surface with few crevices; boulders in shallow water at base; almost vertical, sheltered by Cape Cleveland and Magnetic

INTERTIDAL ORGANISMS ON QUEENSLAND MAINLAND

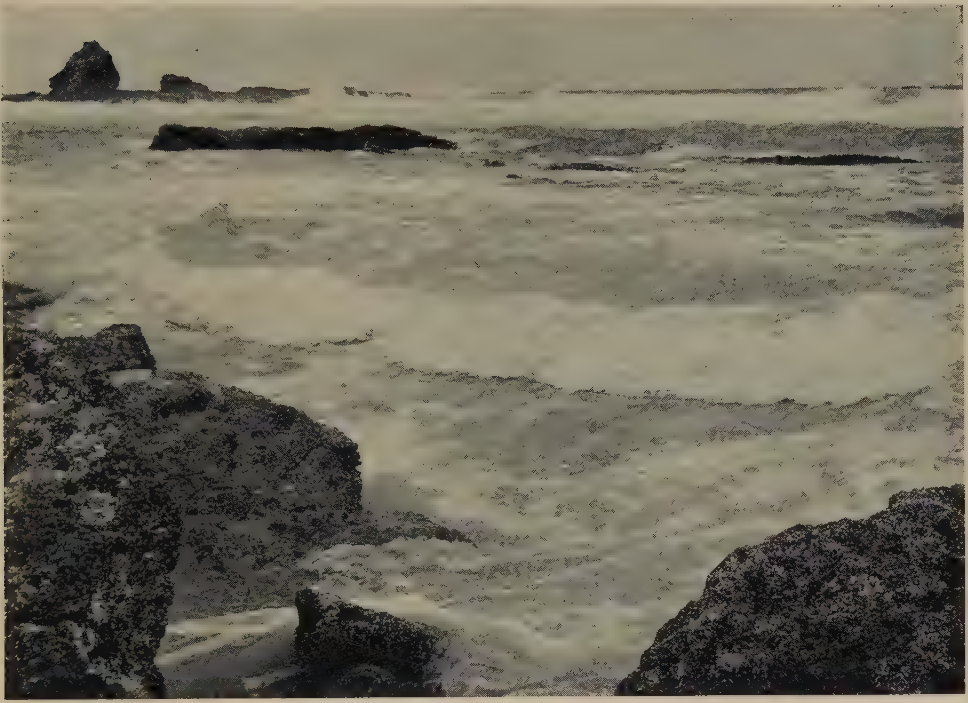

Fig. 1.—Typical wave action at Currumbin, representative of Queensland south coast.

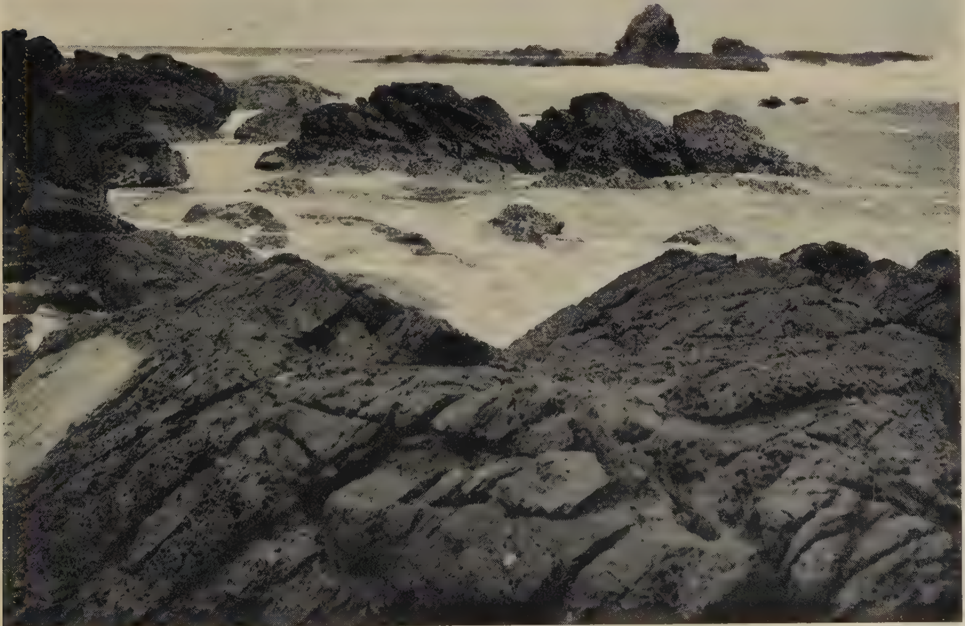

Fig. 2.—Locality where main traverses at Cururmbin were made, photographed at low tide (neap).

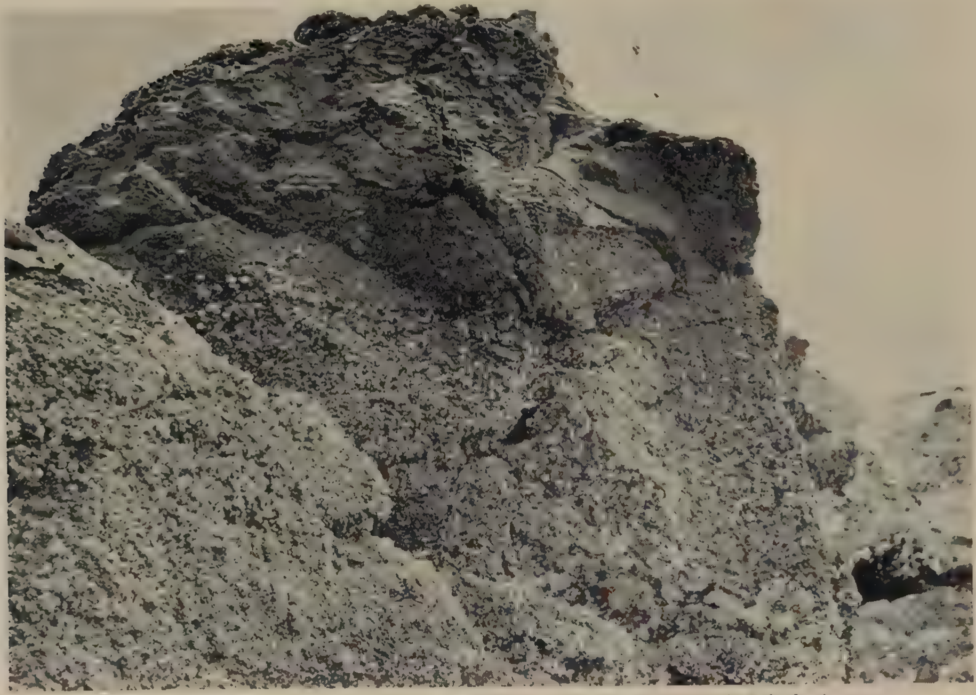

Fig. 1. Rock face at Currumbin, showing littorinid, barnacle, and *Galeolaria* zones.

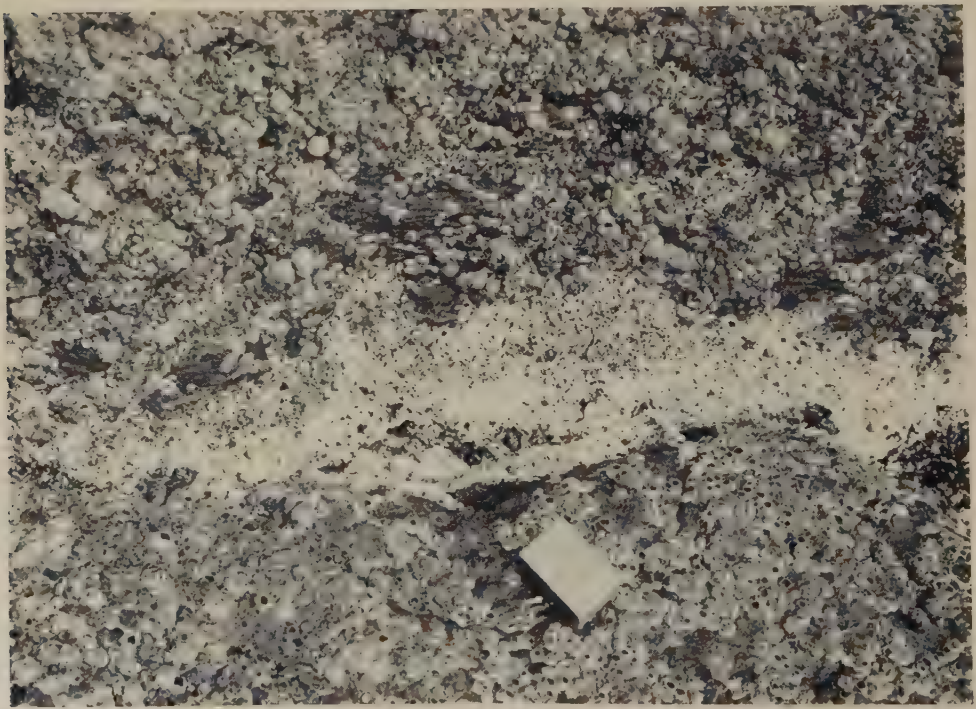

Fig. 2.—Gully in rocks at Currumbin. Walls of gully encrusted with *Galeolaria caespitosa*, above which *Tetraclita rosea* predominates.

INTERTIDAL ORGANISMS ON QUEENSLAND MAINLAND

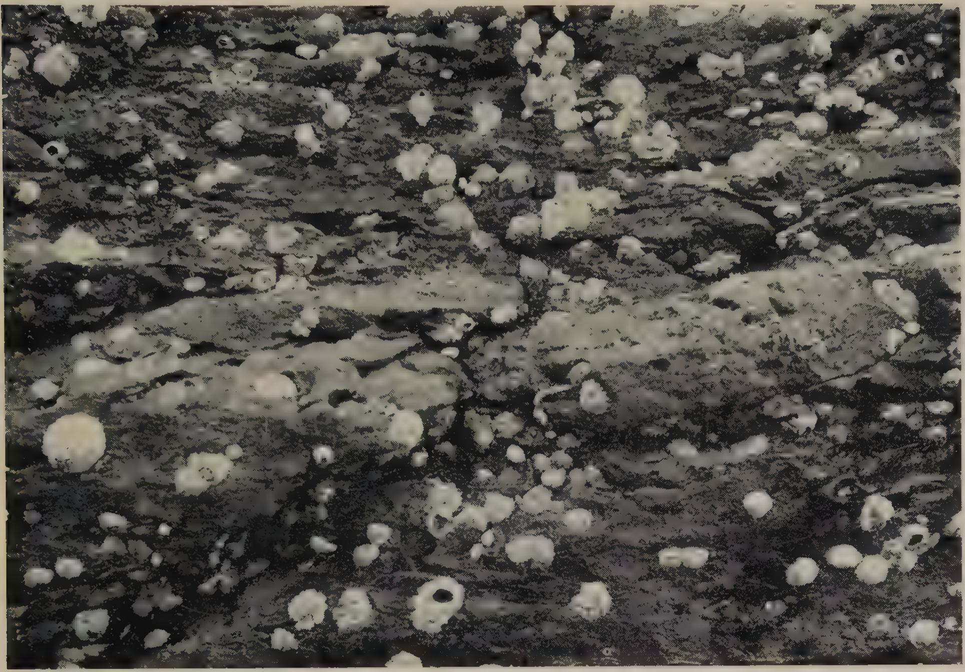

Fig. 1.—*Chthamalus antennatus* zone on rock face at Currumbin. *Melaraphe unifasciata* is also visible in crevices.

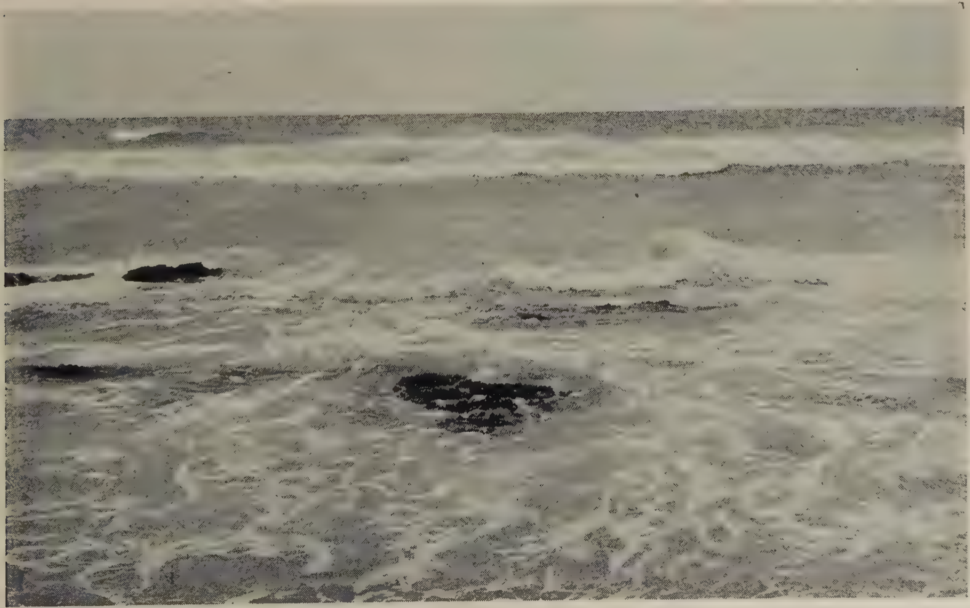

Fig. 2.—*Pyura stolonifera* on outlying rocks at foot of Currumbin traverse, photographed at low tide (neap). Typical surf is visible in the background.

INTERTIDAL ORGANISMS ON QUEENSLAND MAINLAND

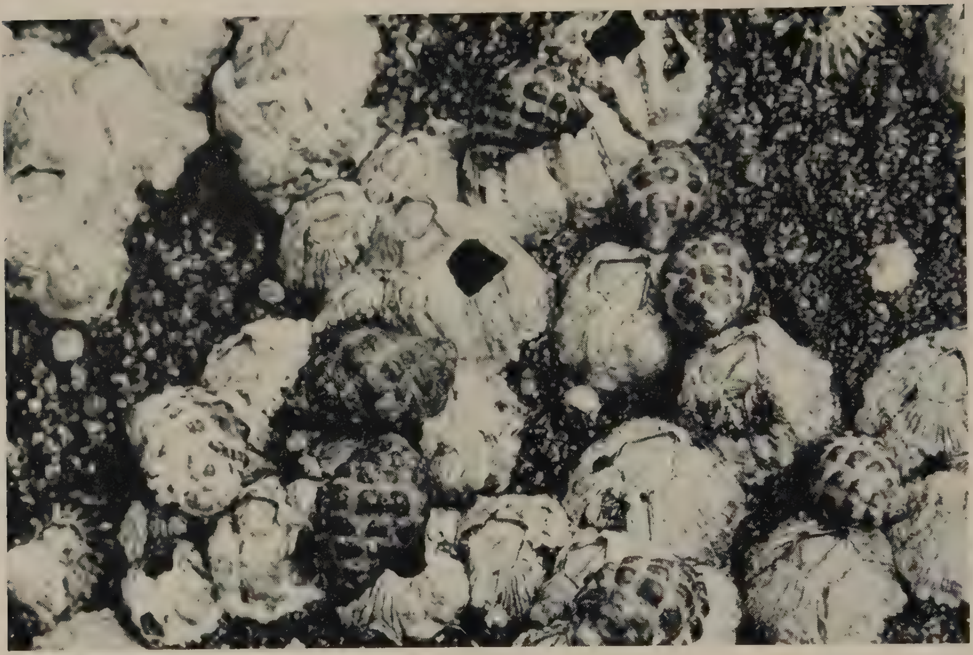

Fig. 1.—*Morula marginalba* feeding on *Tetraclita rosea*, at Caloundra.

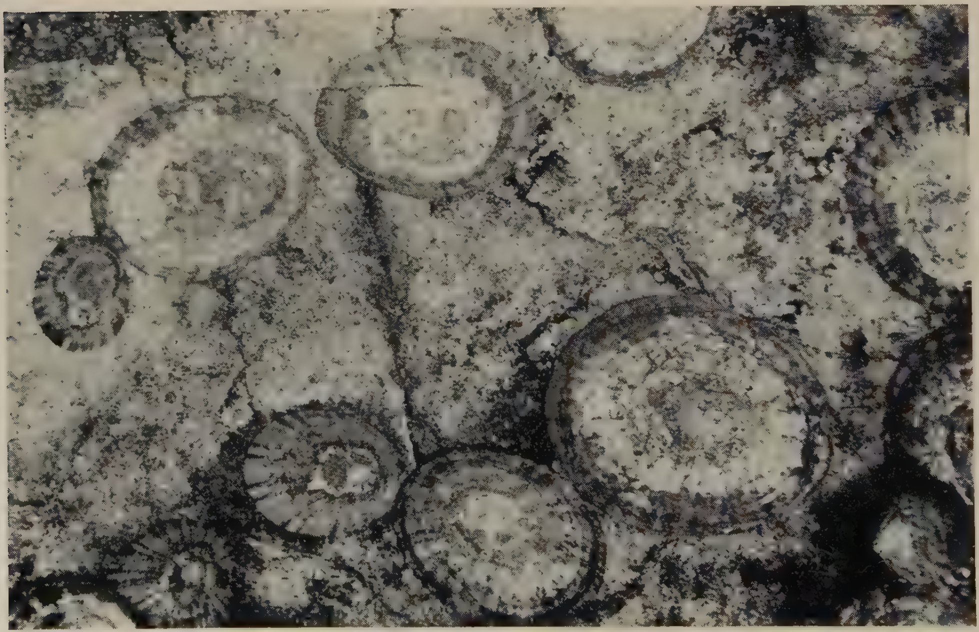

Fig. 2.—*Cellana tramoserica* on rock platform at Caloundra.

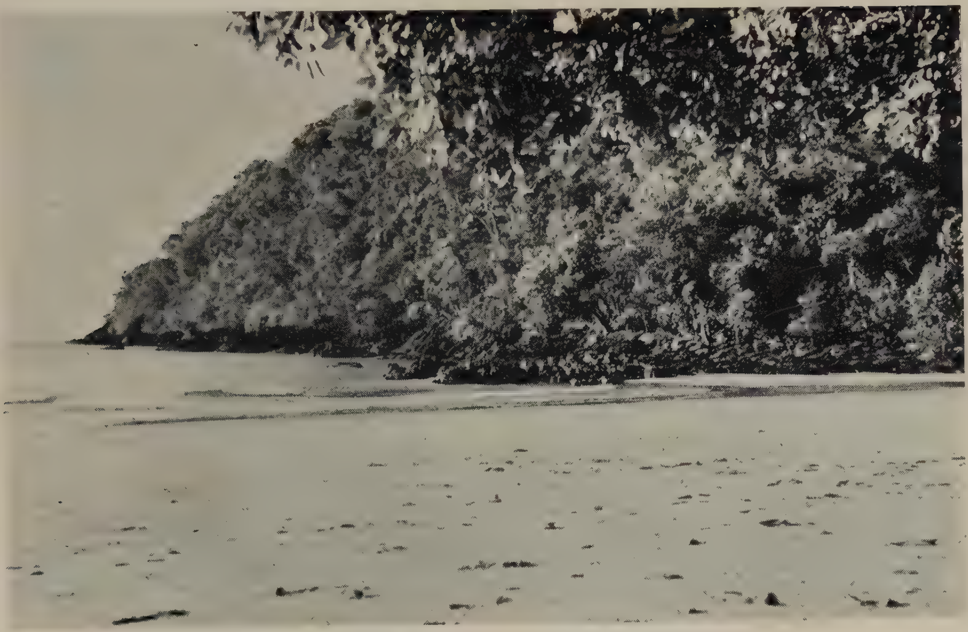

Fig. 1.—View of locality at Etty Bay. Traverses were made on rocks in left background of picture.

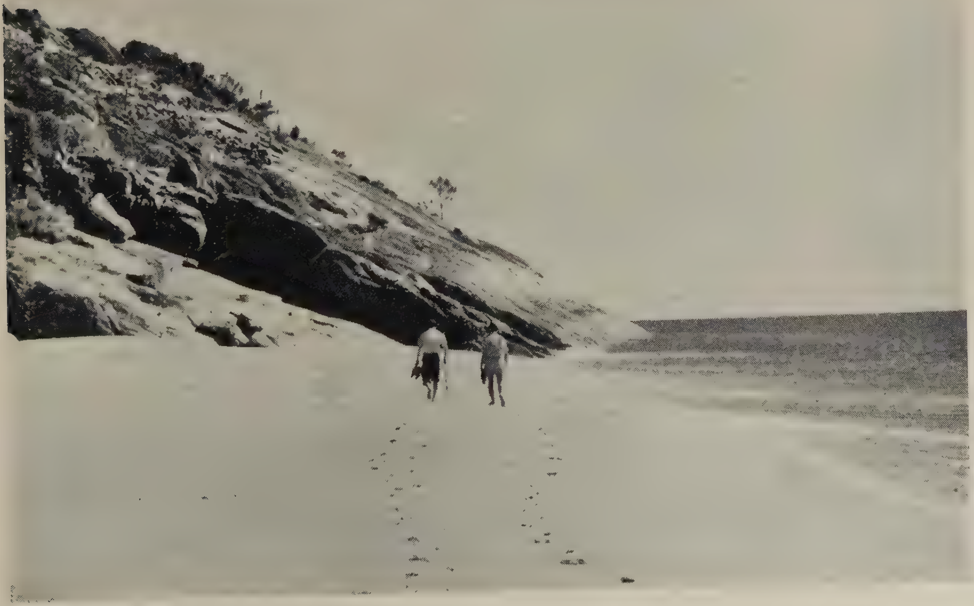

Fig. 2.—Steep sloping rock face at Whitecliffs. Calm sea typical of the region is visible.

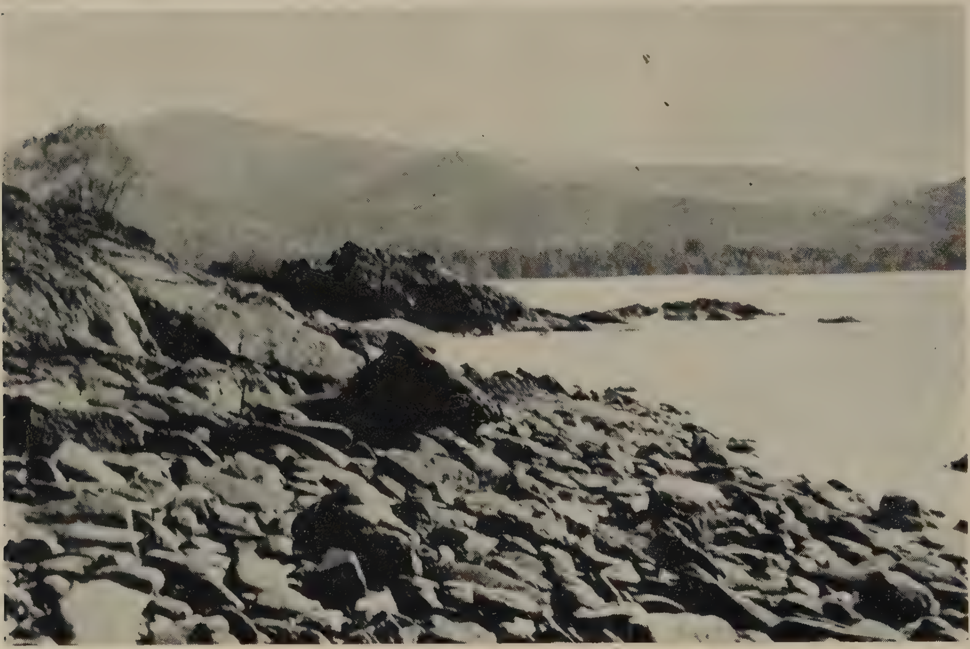

Fig. 1.—Sheltered boulder-strewn beach where traverses were made at Yorkey's Knob.

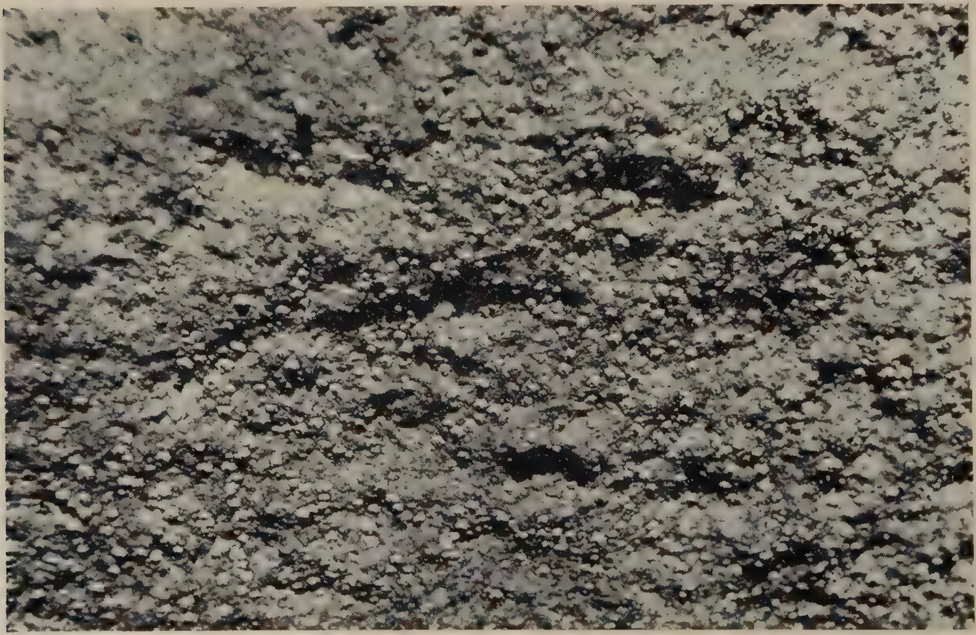

Fig. 2.—*Chthamalus malayensis* zone on rock face at Etty Bay.

INTERTIDAL ORGANISMS ON QUEENSLAND MAINLAND

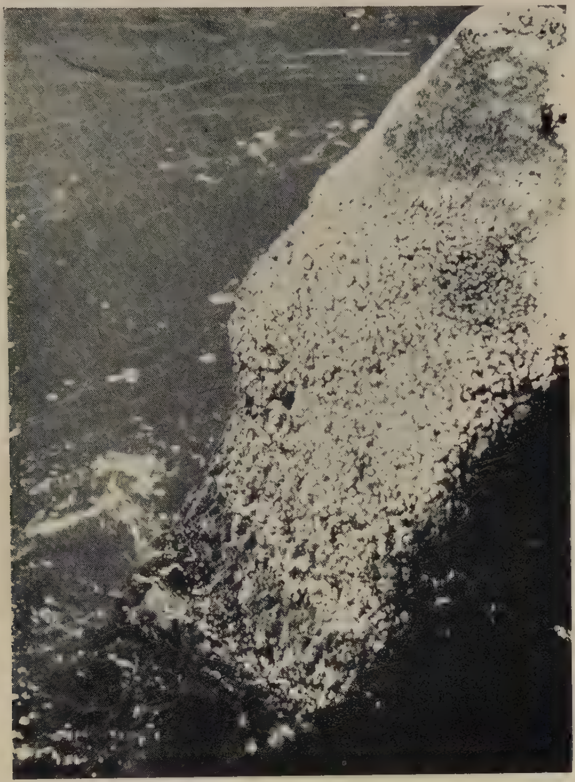

Fig. 1.—*Crassostrea amasa* "pavement" on large boulder at Whitecliffs.

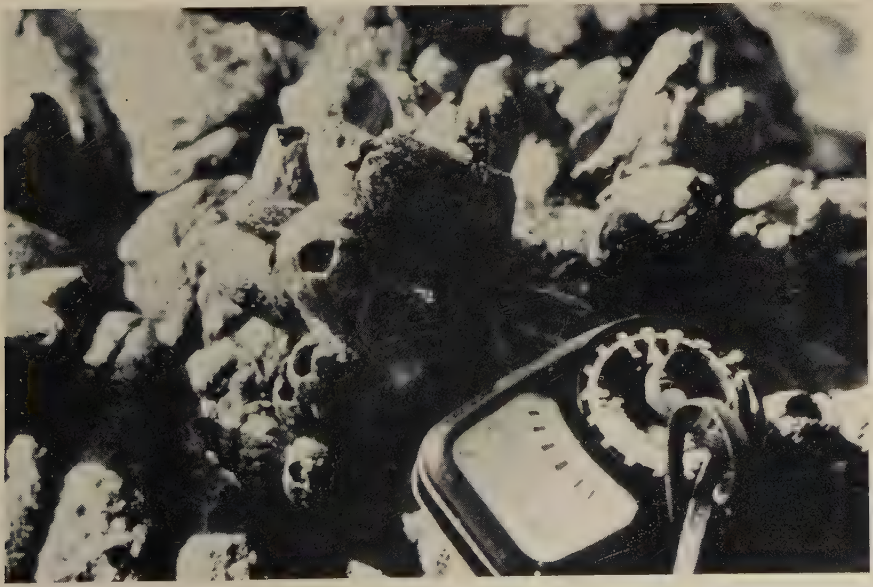

Fig. 2.—*Tetraclita squamosa* on rocks at Yorkey's Knob.

Island; wave action negligible; sand and mud flats exposed in vicinity at low tide; water very turbid.

(23) *Etty Bay.*—Lat. 17° 33′ S., long. 146° 5′ E. Quartzite.
Traverse 1.—Facing NE.; headland S. of beach; rocks jagged and more or less stepped from H.W.S. to below L.W.S.; backed by jungle growing almost to H.W.S.; overall slope about 30°; semi-exposed; wave action slight; water turbid.

(24) *Yorkey's Knob.*—Lat. 16° 48′ S., long. 145° 43′ E. Sericitic schist.
Traverse 1.—Facing NE.; jagged gullied rock face; approx. 45° slope; medium exposure; wave action slight; water turbid.
Traverse 2.—Facing NNW.; rounded boulders; very gentle slope; sheltered; wave action negligible; water turbid.
Traverse 3.—Facing ENE.; jagged and ledged rock face; nearly vertical; exposed; wave action moderate; water turbid.

(25) *Whitecliffs.*—Lat. 16° 39′ S., long. 145° 34′ E. White granite.
Traverse 1.—Facing NE.; innumerable rounded boulders piled one on the other; numerous crevices and shaded overhangs; gently sloping; medium exposure; wave action slight; water turbid.
Traverse 2.—Facing ENE., smooth, steeply sloping (about 60° slope); high cliff; no crevices or gullies but slight pitting of rock surface; exposed; wave action slight; water turbid.

APPENDIX II

The Conspicuous Under-stone and Pool-dwelling Animals Encountered

Species	Ecological Significance	Normal Vertical Range	Where Collected
COELENTERATA			
ALCYONARIA			
Alcyonium sp.	Common	Below L.W.N.	Caloundra, Dunwich
Xenia sp.	V. common	Below L.W.N.	Caloundra, Dunwich
MADREPORARIA			
Acropora variabilis (Klunzinger)	Present	Near M.L.W.	Cape Edgecumbe, Bustard Heads
Cyphastrea serailia (Forskål)	Present	Near L.W.S.	Shoal Point, Bustard Heads
Favia speciosa (Dana)	Common	Near L.W.S.	Caloundra
Goniopora lobata Milne Edwards & Haime	?	Below L.W.S.	Caloundra
Goniastrea pectinata (Ehrenberg)	Common	Near L.W.S.	Cannonvale, Cape Edgecumbe
Leptastrea purpurea (Dana)	Common	Near L.W.S.	Caloundra, Bustard Heads, Coral Point
Pocillopora damicornis (L.)	?	Below L.W.S.	Caloundra
ANNELIDA			
Salmacis dysteri (Huxley)	V. common	Near L.W.N.	Yeppoon

APPENDIX II (*Continued*)

Species	Ecological Significance	Normal Vertical Range	Where Collected
MOLLUSCA			
LORICATA			
Callistellasma antiqua (Reeve)	Common	M.S.L. to L.W.N.	Caloundra, Bargara, Yeppoon
Haploplax arbutum (Reeve)	Present	M.S.L. to L.W.N.	Yeppoon
Heterozona fruticosa (Gould)	Common	Near L.W.S.	Caloundra
Ichnoradsia australis (Sowerby)	Common	Near L.W.N.	Caloundra
Notoplax gabrieli Ashby	Present	Near L.W.N.	Caloundra
GASTROPODA			
Agnewia pseudamygdala (Hedley)	Present	Near L.W.N.	Caloundra, Dunwich, Pt. Vernon, Kissing Pt.
Cerithium dorsuosum Menke	Common	M.S.L. to L.W.N.	Caloundra, Dunwich, Kissing Pt.
Emarginula fuliginea Adams	Common	Near M.S.L.	Yeppoon
Emarginula incisura Adams	Present	Near L.W.S.	Caloundra
Emarginula variegata Adams	Present	Near M.S.L.	Yeppoon
Erronea magnerones Iredale	Common	M.S.L. to L.W.N.	Caloundra, Dunwich, Yeppoon
Fissurella lanceolata Sowerby	Common	L.W.N. to L.W.S.	Pt. Vernon
Hydatina physis (L.)	Present	Near L.W.N.	Yeppoon
Hinea brasiliana Lamarck	V. common	M.S.L. to L.W.N.	Caloundra, Currumbin
Monetraria annulus L.	Common	M.S.L. to L.W.N.	Caloundra, Dunwich, Bargara
Pollia balteata Reeve	Present	Near L.W.N.	Caloundra, Dunwich, Bargara, Kissing Pt.
Thalotia marginata Tenison-Woods	Present	Near L.W.N.	Yeppoon
PELECYPODA			
Gafrarium australe (Sowerby)	Common	Near M.S.L.	Bargara
Pinctada reeveana (Dunker)	Present	Near M.S.L.	Bargara
ECHINODERMATA			
HOLOTHURIOIDEA			
Discucumaria africana (Semper)	V. common	M.S.L. to L.W.N.	Caloundra, Bargara
Holothuria arenicola Semper	Present	Near L.W.N.	Bargara
Holothuria atra Jaeger	Common	Near L.W.N.	Caloundra
Holothuria leucospilota (Brandt)	Common	Near L.W.N.	Caloundra, Bargara, Cape Edgecumbe
Holothuria pardalis Selenka	Common	Near L.W.N.	Bargara
CHORDATA			
ASCIDIACEA			
Amphicarpa elongata Kott	Common	L.W.N. to L.W.S.	Shoal Pt.
Ascidia melanostoma Sluiter	Present	Near L.W.S.	Shoal Pt.
Herdmania momus (Savigny)	Common	L.W.N. to L.W.S.	Shoal Pt., Cannonvale
Polycitor sp.	Common	Near L.W.S.	Currumbin
Didomnun sp.	Common	Near L.W.S.	Shoal Pt.

A PORTABLE RECORDING TIDE GAUGE

By E. P. Hodgkin*

[*Manuscript received June* 6, 1955]

Summary

The gauge is pressure-operated. A copper bellows is connected by plastic tubing to the water, and both bellows and tube are filled with water. Movements of the free end of the bellows are transmitted through a lever system to a marker recording on a revolving drum. The weight of the water is counterbalanced by suspending appropriate weights from the free end of the bellows. Waves are damped by inserting a capillary in the tubing. The instrument records on a scale of 1 in. to 1 ft (the maximum tidal range on the coast of south-western Australia is 5 ft) and it is sensitive to changes of water level of less than 1 in. It is readily portable.

I. Introduction

On the coast of south-western Australia the rocky shores have a peculiar conformation: they are limestone reefs with a platform at about low water level. This fact and the unusual tidal pattern emphasized that, for a proper study of the littoral ecology, it was necessary to know the exact height of the reefs relative to a fixed datum, in this case at Fremantle, W.A. Only so could records from the tide gauge there be used to determine the relative periods during which individual reefs, and parts of the reefs, are exposed.

Ordinary survey levelling would have been impracticable over the distances involved and across water, and it was decided to estimate the heights by comparing the level of the water on the reefs with readings on the recording tide gauge at Fremantle. The daily range of the tide on this coast is from 1 to 3 ft; the total annual range is a little over 5 ft. A gauge sensitive to movements of 1 in. was therefore desirable. Initially, a still pool and float was used, and this was read at intervals over the period of low tide. This did not prove sufficiently accurate and a simple portable pressure-recording gauge was developed, with which to record tidal movements. These instruments are described below.

II. Still Pool and Float

This consists of a 6 ft length of $2\frac{1}{2}$ in. dia. galvanized iron pipe closed at one end, with a hole about 0·5 mm drilled near the closed end. A cork float supports a length of light wood marked in feet and decimals of a foot (the graduations on the Fremantle gauge).

The instrument effectively damps wave action and gives true readings, at the time of reading. Reasonable approximations to the true levels are obtained, under favourable conditions to within 2-3 in.

In practice the instrument has serious limitations. Firstly, there is often difficulty in finding a suitable site at which to operate it. Secondly, because the

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* Department of Zoology, University of Western Australia.

time of low water is not known accurately in advance, it is necessary to take readings over some hours. Finally, because the tidal range on the reefs often differs from that at Fremantle, it is necessary to take readings over both high and low water.

A more serious disadvantage is that the degree of accuracy is insufficient. The inaccuracy is partly inherent in the instrument, but arises also from seiche-type oscillations with periods of about 15 min. These oscillations are common features, and wrong estimates of the true level are made by the chance of reading the gauge at the crests or troughs. When readings taken over 24 hr were plotted against the record on the Fremantle gauge they differed by 2-3 in., whether because of seiches or of purely local or instrumental factors is not known. Three inches is a third of the diurnal range at neap tides.

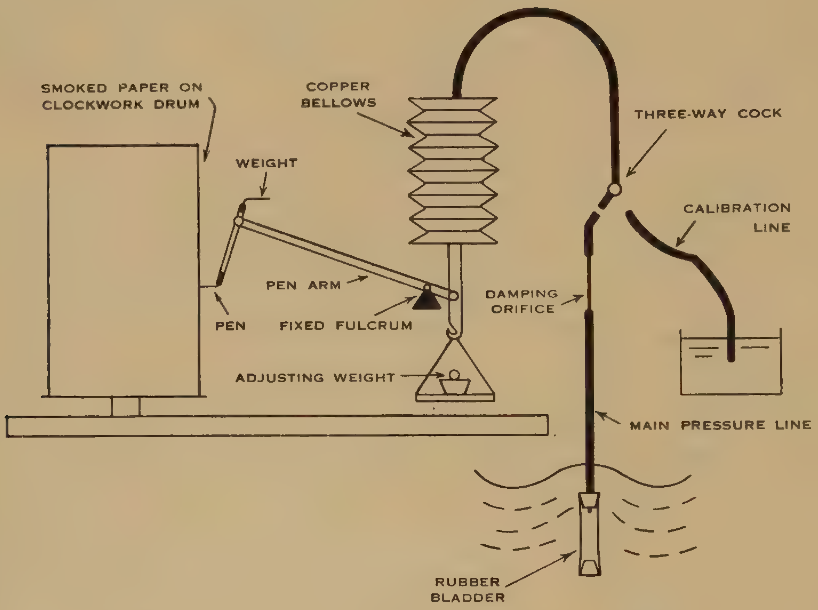

Fig. 1.—Construction of portable recording tide gauge.

III. Recording Gauge

This consists essentially of a copper bellows the upper end of which is fixed and is connected by a tube to the sea; both bellows and tube are filled with water. The free lower end of the bellows is closed, and is connected by a lever system to a marker recording on a revolving drum (Fig. 1).

The bellows used has an external diameter of $1\frac{1}{2}$ in. and a length of 2 in. when not stressed; it shortens about 0·1 in. for every 3-ft fall in water level. The lever system is devised to convert this travel to a movement at the end of the writing arm of 1 in. for every foot change in water level.

A simple frontal writing lever records on smoked kymograph paper. A writing pen could be used if desired. The drum (from an old barograph) can be adjusted to make one revolution in either 24 hr or 7 days.

Thick-walled plastic tubing of about $\frac{1}{4}$ in. internal diameter is used, of sufficient length to reach to open water; in one instance this was 50 yd.

It has been found satisfactory to leave the end of the tube open when the instrument is operated for a day or two at a time. For use over longer periods it is preferable to prevent the water in the tubing being replaced by sea-water, because air dissolved in the sea-water comes out of solution and, collecting in the tube, vitiates the record. The end of the tube is covered with a rubber bladder, also filled with water; this must remain flaccid so that the rubber does not offer resistance to pressure changes (a short length of bicycle inner tube is a convenient bladder).

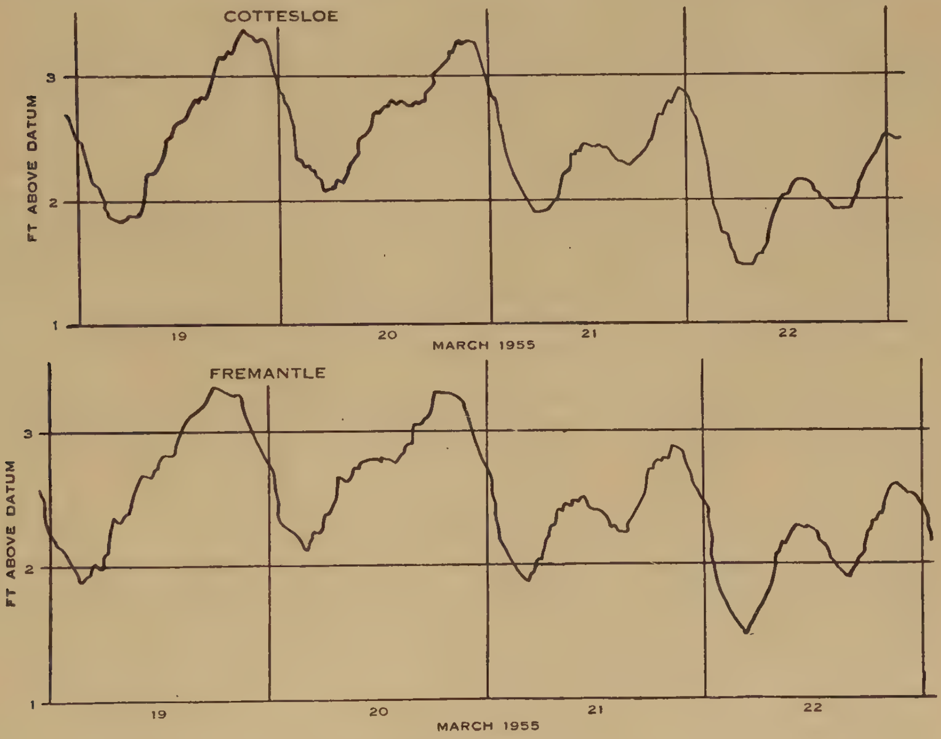

Fig. 2.—Tide records compared (traced from original records). Above, from portable gauge; below, from Bailey's gauge at Fremantle.

To damp the effect of waves a capillary tube of 0·2 mm internal diameter is inserted in the upper end of the tube. A tap and an alternative line permit rapid adjustment and calibration. The tap is greased with a good-quality grease, e.g. "Apiezon".

The gauge can be sited at any reasonable height above the water; it has regularly been used at up to 8 ft. To compensate for the weight of water supported, weights are hung from the lower end of the rod connecting the free end of the bellows to the lever arm. One lb weight is added for each 2 ft the gauge is raised above sea-level. A convenient set of weights is $\frac{1}{2}$, 1, 2, and 4 lb. The instrument is enclosed in a stout wooden box.

IV. Operation

In use, the instrument is placed on rock as close as possible to open water and is roughly levelled. The end of the tube, with a sinker attached, is placed in the sea (if an open-ended tube is being used the bung which closes it in transit is removed). The instrument is first adjusted with the calibration tube, weights being added to the pan until the marker records on the appropriate part of the drum; the tap is then turned to connect the bellows with the main tube. The paper can be smoked at the site or before transport to it. If the counterweight is removed from the end-marker there is no damage to the instrument, or to the smoked paper, from transport over rough tracks.

To calibrate the instrument the end of the calibration tube is placed in a bucket of water at a known height, the tap is turned to place this tube in communication with the bellows, the marker is allowed to come to rest, and the drum marked. The slack of the tube must be above the level of the water in the bucket.

The instrument is very sensitive and changes of less than an inch in water level show clearly on the record. It gives a clean trace on both 24-hr and 7-day settings. The record is comparable to that of a large fixed instrument recording mechanically, such as that used by the Fremantle Harbour Trust. The similarity between the two records in Figure 2 is evident. The Fremantle gauge is near the entrance to the harbour; Cottesloe is on the open sea 3 miles north. The apparent time lag is due to the Fremantle clock being slow.

The instrument is portable and has been carried up and down steep hills and over rocks, by one person when necessary. The weights can of course be carried separately.

V. Acknowledgments

The expenses of this investigation were defrayed from a University Research Grant. To Mr. R. Silvester, Lecturer in Civil Engineering (Hydraulics), University of Western Australia, I am indebted for drawing the diagram of the instrument.

THE FAMILY CERITHIOPSIDAE (MOLLUSCA) FROM THE SOLANDERIAN AND DAMPIERIAN ZOOGEOGRAPHICAL PROVINCES

By C. F. Laseron*

[*Manuscript received June* 22, 1955]

Summary

This paper reviews the Cerithiopsidae (Mollusca) from the Solanderian and Dampierian Zoogeographical Provinces in northern Australia. In all, 10 genera and 46 species or subspecies are described and figured, and of these six genera and 42 species or subspecies are proposed as new. A key to the Australian genera is also given, and the species from the Peronian and Maugean Provinces have been revised to fit in with the proposed classification.

I. Introduction

This paper is believed to be the first attempt to study systematically the small molluscs living in northern Australian seas. The term "small" is relative, and is here used for those shells which are about 5 mm or less in size. The whole field is an enormous one, and one that generally has been neglected in favour of the many larger and more obvious forms. In the light of present knowledge the total number of species of the smaller molluscs can only be surmised, but it must run into many thousands, of which the great majority are as yet undescribed. It is possible in any one locality on the Queensland coast, on the Barrier Reef, or in the Northern Territory, to collect within a few days upwards of a thousand species belonging to the Rissoidae, Liotiidae, Pyramidellidae, Triphoridae, and many other known families of small gasteropods and pelecypods, in addition to many of uncertain classification, belonging to what are probably quite new families.

How to approach such a large task requires much thought. The late Charles Hedley did a great deal of valuable pioneering work. He made and described collections from the Hope Islands and Masthead Island, and described other new species in his various "Studies of Australian Mollusca". This, however, did little more than scratch the surface. It is thought that a better way is to monograph each group or family by itself, illustrate every known or undescribed species, and by collating information, form a foundation on which other conchologists can build. In the similar but smaller field of the Peronian Zoogeographical Province, corresponding nearly to the coast of New South Wales, the author has already endeavoured to do this, and has published a number of papers on these lines. Though the Peronian small molluscs had been in the past more intensively collected and described than those of Queensland, it is surprising how much new material was brought to light by this method, though even here the whole task is far from complete.

It is hoped that this paper will be a stimulus for others to work along the same lines. The first necessity is for intensive collecting of the small molluscs from as

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many localities as possible, the second the specialized study of each group or family, and the third the comparative study of relationships with similar families in the other provinces of the Australian region, and finally with those from other parts of the world.

The family Cerithiopsidae has been chosen as the subject of this first paper for various reasons. The author has already reviewed the same family from the Peronian Province, and the experience gained has greatly facilitated the work. The family also has always been regarded as peculiarly difficult, and this in the past has led to its almost complete neglect. In the Pacific a few species have been described from New Caledonia by Melvill and Standen (1896), and from Funafuti by Hedley (1899). From Queensland (Solanderian) one species was collected by the Challenger Expedition (1886), and four were described from the Hope Islands by Hedley (1909). Nothing whatever is known of the Dampierian species.

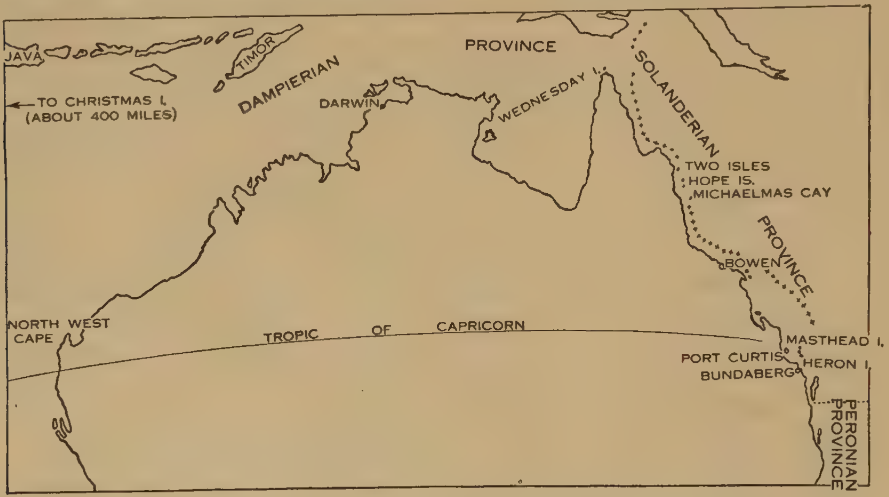

JAVA
TIMOR
TO CHRISTMAS I. (ABOUT 400 MILES)
DAMPIERIAN
PROVINCE
DARWIN
WEDNESDAY I.
SOLANDERIAN
TWO ISLES
HOPE IS.
MICHAELMAS CAY
PROVINCE
BOWEN
NORTH WEST CAPE
TROPIC OF CAPRICORN
MASTHEAD I.
PORT CURTIS
HERON I.
BUNDABERG
PERONIAN PROVINCE

Fig. 1.—Northern Australia, showing localities from which material was obtained.

Most of the material available for study is believed to be in Sydney. Specimens are not only small, but are inconspicuous, and are generally overlooked by all but the keenest of collectors. In the Australian Museum, Sydney, are collections made by Hedley from the Hope Islands and Masthead Island, and by T. Iredale from Michaelmas Cay. Other odd specimens are from various localities on the Queensland coast. To these must now be added material collected by my son John Laseron from Bowen and Caloundra on the mainland coast, and from Heron Island in the Capricorn Group. From these collections a fairly comprehensive picture may be given of the family in Queensland waters, though it is probably far from complete. In addition a few species from the Dampierian Province of northern Australia give a glimpse of a different fauna, and one which as yet is largely unknown (see Fig. 1).

Apart from the description of species, it is not yet possible to draw more than a few tentative general conclusions. The number of species is now increased from five to over 40, but it is probable that when all are known, the complete list will run well into three figures. In the material examined were many specimens apparently belonging to further undescribed species, but they were too worn or broken for certain identification. Another fact which suggests even greater variety is that different localities, if only a hundred miles apart, have very few species in common. It is possible that the family is at the height of its evolution, and genera such as *Joculator* and *Horologica* particularly are so specialized that each island or group of islands has its own species or race, in the same way that certain land shells have a narrow and circumscribed range.

More work has been done on the family from southern Australian waters than from the north. May (1923) listed 10 species from Tasmania under the generic names *Cerithiopsis* and *Seila*. Tasmania and Bass Strait have since been recognized as a separate zoogeographical province, the Maugean. Cotton (June 30, 1951) reviewed the Australian forms generically and listed 20 Recent and 11 Tertiary species from the Flindersian Province. By a coincidence the author's own paper (Laseron 1951) on the New South Wales (Peronian) Cerithiopsidae was printed independently only a month later, on July 31 of the same year. Fortunately none of the new genera there described clashed with those used or proposed by Cotton, so there are no synonyms to be corrected. Nevertheless, in light of Cotton's work and from further knowledge gained from the many new species from northern Australia, further generic revision is needed, not only for the Solanderian fauna but for that of the Peronian Province as well. In all 42 species were discussed from the Peronian Province.

From Queensland (Solanderian) and the Barrier Reef (separated by some zoologists as a separate province, the Banksian) 41 species and subspecies, most of them new, are now discussed. Five new species are also described from the north-west (Dampierian). When the full fauna is known it is probable that the list will grow to over 100 from each province.

The classification of the Cerithiopsidae is still largely empirical; that is, it is based on shell characters alone, and nothing is known of the anatomy or life history of Australian species. Even when material is collected alive, the small inconspicuous shells are rarely seen until they have been long dead and sorted out from a mass of unrelated species. Even the operculum is then rarely obtainable. Fortunately the heavily sculptured shells give ample characters for identification, though even under the microscope, particularly when the surface is shining, great care must be taken to view them from different angles in order to ascertain the details.

The protoconch, as with most gasteropods, is very important, and is often the surest way to separate two species otherwise very similar. It is a constant specific character, and may occasionally be used generically, as with *Specula* and *Potenatomus*. Colour is not claimed as a true specific character, but when distinctive is a very useful guide for quick recognition, as it seems remarkably constant in each species.

Cotton (1951) published a very useful key to Australian genera, established mainly on the protoconch, but using other shell characters as well. This is now slightly altered and expanded to include the additional material in this and the previous paper on Peronian forms.

KEY TO THE AUSTRALIAN GENERA OF THE FAMILY CERITHIOPSIDAE

1.	Sculpture both spiral and transverse, generally tuberculate	2
	Sculpture otherwise (spiral or axial)	11
2(1).	Spire short, convex and inflated	3
	Spire elongate (narrow or carrot-shaped)	5
3(2).	Protoconch subulate, smooth	4
	Protoconch inflated, 1½ whorls	*Potenatomus*, gen. nov.
4(3)	Three rows of tubercles to whorl	*Joculator* Hedley
	Two rows of tubercles to whorl	*Horologica*, gen. nov.
5(2).	Spire like an inverted carrot (3 rows defined tubercules, protoconch subulate)	*Conciliopsis*, gen. nov.
	Spire elongate and narrow	6
6(5).	Spire turreted (sutures deep, clathrate)	7
	Spire not turreted	8
7(6).	Protoconch smooth, subulate	*Clathropsis*, gen. nov.
	Protoconch reticulate	*Zaclys* Finlay
8(6).	Spire cylindrical, sutures deep	9
	Whorls flat, sutures shallow	10
9(8).	Protoconch smooth, subulate	*Synthopsis*, gen. nov.
	Protoconch 1½ whorls, inflated	*Specula* Finlay
10(8).	Protoconch smooth, subulate	*Tubercliopsis*, gen. nov.
	Protoconch short, transversely striate	*Socienna* Finlay
11(1).	Sculpture of axial ribs (protoconch 2 smooth whorls)	*Altispecula* Powell
	Sculpture spiral	12
12(11).	Sculpture of spiral keels, weakly indented	13
	Sculpture of smooth spiral keels only	14
13(12).	Three keels, protoconch inflated	*Binda* Laseron
	Four keels, protoconch transversely striate	*Pilaflexis* Laseron
14(12).	Spire elongate, flat or turreted	15
	Spire short, convex and inflated	*Paraseila* Laseron
15(14).	Spire elongate and flat, base excavate	*Notoseila* Finlay
	Spire elongate, turreted, many thin spiral keels	16
16(15).	Protoconch subulate	*Seilarex* Iredale
	Protoconch short, mammilate	*Euseila* Cotton

The following is a complete list of the species discussed in this paper as from the Solanderian and Dampierian Provinces.

SOLANDERIAN PROVINCE

Tubercliopsis capricornia, sp. nov.; *T. punicea*, sp. nov.; *T. lata*, sp. nov.; *T. elongata*, sp. nov.; *T. bowenensis*, sp. nov.

Clathropsis impedita, sp. nov.; *C. mellita*, sp. nov.; *C. turreta*, sp. nov.; *C. maritima*, sp. nov.; *C. thornleyana*, sp. nov.

Synthopsis cylindrica, sp. nov.; *S. columna*, sp. nov.; *S. columna infans*, subsp. nov.; *S. demissa*, sp. nov.; *S. radix*, sp. nov.

Conciliopsis carrota, sp. nov.

Specula queenslandica, sp. nov.

Joculator continens, sp. nov.; *J. subula*, sp. nov.; *J. melania*, sp. nov.; *J. varians*, sp. nov.; *J. albordina*, sp. nov.; *J. ovata*, sp. nov.; *J. tomacula*, sp. nov.; *J. tomacula propinqua*, subsp. nov.; *J. tribulationis* Hedley; *J. minima*, sp. nov.

Horologica bicolor, sp. nov.; *H. albino*, sp. nov.; *H. bipartita*, sp. nov.; *H. purpurea*, sp. nov.; *H. westiana* (Hedley); *H. minareta*, sp. nov.; *H. telegraphica* (Hedley); *H. pinea* (Hedley); *H. pinea nigrophyla*, subsp. nov.

Notoseila iredalei, sp. nov.; *N. capricornia*, sp. nov.

Paraseila heronsis Laseron; *P. ampulla*, sp. nov.

DAMPIERIAN PROVINCE

Clathropsis darwinensis, sp. nov.

Joculator ridicula (Watson).

Potenatomus caputumere, sp. nov.; *P. secundus*, sp. nov.

Horologica macrocephala, sp. nov.

The following list is of Peronian species now revised generically.

Socienna jacksonensis (Laseron); *S. quadrispiralis* (Laseron); *S. gregaria* (Laseron); *S. angasi* (Semper); *S. clava* (Laseron); *S. crassa* (Laseron); *S. hebes* (Laseron).

Tubercliopsis filofusca (Laseron); *T. quinquepilia* (Laseron); *T. infracolor* (Laseron); *T. septipilia* (Laseron); *T. macalpinei* (Laseron); *T. georgensis* (Laseron); *T. exigua* (Laseron); *T. literalis* (Laseron).

Clathropsis tripilia (Laseron); *C. alternata* (Laseron); *C. bicarinata* (Laseron).

Synthopsis cancellata (Laseron); *S. virgula* (Laseron); *S. exilis* (Laseron).

Joculator hedleyi Laseron; *J. minor* Laseron; *J. gracilis* Laseron.

Potenatomus nanus Laseron.

Binda tasmantis Laseron; *B. cacuminatus* (Hedley).

Pilaflexis regularis Laseron; *P. oculis* Laseron.

Notoseila maculosa (Laseron); *N. crocea* (Angas); *N. albosutura* (Tenison-Woods); *N. magna* (Laseron); *N. tenuis* (Laseron); *N. nigrofusca* (Laseron).

Paraseila halligani (Hedley).

Seilarex attenuata (Hedley); *S. turretelliformis* (Angas).

Amongst Flindersian species, under this new revision, most will retain the generic names as given by Cotton (1951), but *Joculator flindersi* Cotton will be transferred to *Horologica*.

Maugean species need complete generic revision. From May's (1923) figures they fall into the new classifications as follows:

Tubercliopsis cessicus (Hedley); *T. dannevigi* (Hedley).

Socienna apicostata (May).

Synthopsis semilaevis (Tenison-Woods); *S. trisculpta* (May).

Specula mamilla (May); *S. turbonilloides* (Tenison-Woods).

Notoseila albosutura (Tenison-Woods); *N. crocea* (Angas).

Paraseila halligani (Hedley).

Seilarex turritelliformis (Angas).

II. Description of Species

All holotypes and paratypes, as well as specimens illustrated, are either already in the Australian Museum, Sydney, or are now presented to that institution.

Genus TUBERCLIOPSIS, gen. nov.

Type species *Tubercliopsis capricornia*, sp. nov.

Elongate shells with flat whorls, the sutures hardly indented, protoconchs subulate, continuing the line of the spire. Base excavate. Sculpture of 3 or 4 rows of rounded tubercles, sometimes connected transversely by ridges to make the sculpture slightly clathrate.

TUBERCLIOPSIS CAPRICORNIA, sp. nov.

Figs. 2 and 3

Shell of medium size, elongately conical, deep red-brown. Protoconch of 3 whorls, smooth, yellowish brown, the apex acuminate, the whole terminating abruptly with a very faint varix. Mature whorls 8, increasing regularly, sides flat, the sutures shallow but distinct. Sculpture of 3 spiral keels, a plain 4th keel on the base of the body whorl, the keels broken into large, regular, rounded tubercles, about 17 to the whorl, and connected row to row by barely discernible transverse ridges. Base excavate. Aperture subquadrate, outer margin straight and thin, indented by the sculpture, canal short, straight, wide and open, columella rather narrow, anteriorly oblique and acuminate. Length 4·9 mm.

Locality.—Heron I., Capricorn Group, Qld., not uncommon alive under coral boulders (J. Laseron), holotype and 20 paratypes.

Remarks.—This resembles some of the Peronian species of the genus, but differs from all these in the protoconch.

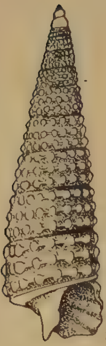
TUBERCLIOPSIS PUNICEA, sp. nov.

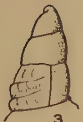
Fig. 4

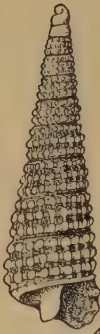
Shell of medium size, elongate conical, rather variable in relative width, white, tinged with delicate mauve-pink. Protoconch white and vitreous, 2½ whorls, terminating in a slight varix, stouter than in *T. capricornia*, and with a more obtuse apex. Mature whorls 8, increasing regularly, flat, sutures distinct and relatively deep. Sculpture of 3 keels, a 4th smooth keel on the base of the body whorl, the keels broken into prominent rounded tubercles, about 19 to the whorl, connected by distinct transverse bars from row to row, producing a slight cancellation. In the earlier whorls the topmost row is slightly smaller than the others, making the whorls slightly rounded. Base excavate. Aperture subquadrate, the outer margin thin and indented by the sculpture, canal short, straight, broad and open. Columella short, narrow, rounded anteriorly. Length 4·5 mm.

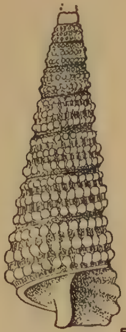
Locality.—Michaelmas Cay (T. Iredale), holotype and 4 paratypes.

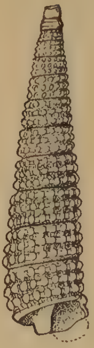
Remarks.—This is very close to *T. capricornia*, and opinions may vary as to whether the difference is specific or merely racial. The colour affords a ready recognition point, but more important is the difference in the protoconch, that

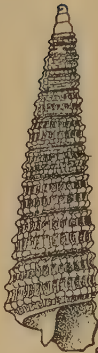


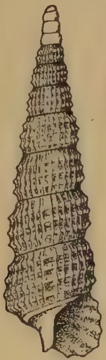


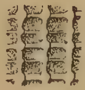


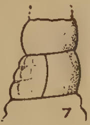


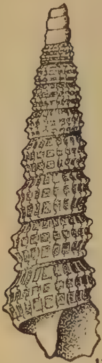


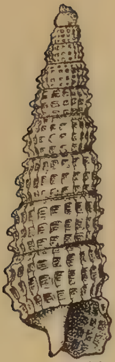


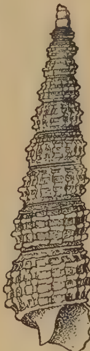


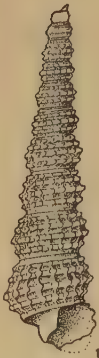


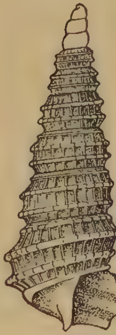


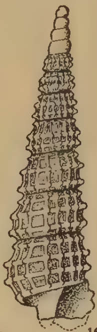


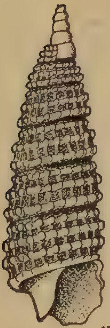


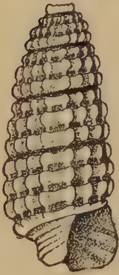


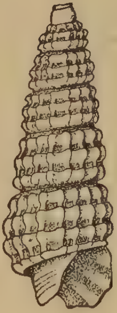


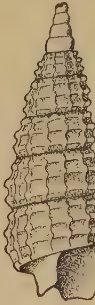












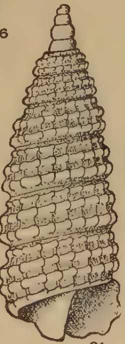


Fig. 2.—*Tubercliopsis capricornia*, sp. nov. Holotype. × 9. Fig. 3.—*T. capricornia*. Protoconch. Fig. 4.—*T. punicea*, sp. nov. Holotype. × 9. Fig. 5.—*T. lata*, sp. nov. Holotype. × 10. Fig. 6.—*T. elongata*, sp. nov. Holotype. × 9. Fig. 7.—*T. elongata*. Protoconch. Fig. 8.—*T. bowenensis*, sp. nov. Holotype. × 7. Fig. 9.—*Clathropsis impedita*, sp. nov. Holotype. × 13. Fig. 10.—*C. impedita*. Details of sculpture. Fig. 11.—*C. mellita*, sp. nov. Holotype. × 10. Fig. 12.—*C. turreta*, sp. nov. Holotype. × 10. Fig. 13.—*C. turreta*. Another specimen. × 8·5. Fig. 14.—*C. maritima*, sp. nov. Holotype. × 8·5. Fig. 15.—*C. darwinensis*, sp. nov. Holotype. × 14. Fig. 16.—*C. thornleyana*, sp. nov. Holotype. × 10. Fig. 17.—*Synthopsis cylindrica*, sp. nov. Holotype. × 13. Fig. 18.—*S. columna*, sp. nov. Holotype. × 20. Fig. 19.—*S. columna infans*, subsp. nov. Holotype. × 22. Fig. 20.—*S. demissa*, sp. nov. Holotype. × 16. Fig. 21.—*S. radix*, sp. nov. Holotype. × 14.

in *punicea* being altogether stouter and of a different texture. There are also slight differences in the sculpture and in the columella. The species is somewhat variable in width, and one extremely attenuate specimen has 7 normal whorls, and after suffering a fracture, has added 4 more whorls, all approximately the same size.

TUBERCLIOPSIS LATA, sp. nov.

Fig. 5

Shell of medium size, elongate conical, white with pink tinge. Protoconch broken in type, but apparently subulate, and probably of several whorls. Mature whorls 7 (may not be quite mature), flat, sutures distinct and relatively deeply impressed. Sculpture of 3 keels with deep channels between, a 4th plain keel on the base of the body whorl, the keels broken into numerous closely packed, raised, rounded tubercles, about 26 to the whorl, practically touching each other, and connected from row to row by narrow, transverse bars, producing a slight cancellation. Aperture subquadrate, outer margin thin, indented by the sculpture, canal broad and open. Columella rounded anteriorly and slightly curved. Length 4·1 mm.

Locality.—Two Isles, Cape Flattery (C. Hedley), holotype.

Remarks.—This again approaches closely to the 2 previous species, but differs chiefly by being broader, and by the more numerous and closely packed tubercles.

TUBERCLIOPSIS ELONGATA, sp. nov.

Figs. 6 and 7

Shell of medium size, very elongate and narrow, conical, the upper part of the spire slightly convex, colour uniformly yellowish white. Protoconch of the type not perfect, only 1½ whorls remaining, but these are smooth and vitreous, terminating in a slight curved varix. Mature whorls 11, flat, sutures distinct but very slightly impressed. Sculpture of 3 sharply raised keels, a 4th smooth keel on the body whorl, separated by deep channels, the main keels broken into ill-defined small tubercles, about 18 to the whorl, and connected row to row by low transverse ridges, but not sufficiently defined to produce a cancellation. Base excavate. Aperture subquadrate, outer margin thin and indented by the sculpture, canal wide and shallow, columella short, relatively broad, and rounded anteriorly. Length 5 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype.

Remarks.—This is the longest and narrowest of the species here discussed, and the small irregular tubercles, only visible in a strong lateral light, give it a distinct facies.

TUBERCLIOPSIS BOWENENSIS, sp. nov.

Fig. 8

Shell elongate, narrow, conical, colour brown when fresh, but fading to a dull yellow. Protoconch of 3½ whorls, slender, smooth, and translucent, no varix observable. Mature whorls 9, with flattened sides, the sutures distinct and relatively deep. Sculpture of 3 narrow, prominent keels, surmounted by small, well-defined, rounded tubercles, about 30 on the body whorl, fewer on the earlier whorls, a 4th smooth keel on the body whorl. The tubercles are connected row to row by well-defined, sharp, narrow, transverse ridges, producing a series of deep pits between them, and a much more cancellate structure than in the other species. Base excavate. Aperture subquadrate, outer margin thin, indented by the sculpture, the canal broad, short, and rounded. Columella short, narrow, anteriorly oblique, and acuminate. Length 6·5 mm.

Locality.—Bowen, Qld., alive under rocks (J. Laseron), holotype and 1 paratype.

Remarks.—This differs from all the other species of *Tubercliopsis* here discussed by its very numerous and small tubercles. By its clathrate sculpture it approaches the next genus, *Clathropsis*, but it is kept within *Tubercliopsis* by its flat whorls and the clear definition of the tubercles.

Genus CLATHROPSIS, gen. nov.

Type species *Clathropsis impedita*, sp. nov.

Elongate, sometimes very attenuate shells, with 7 or more mature whorls, turreted, the whorls more or less rounded, with the sutures very deeply impressed. The protoconch is subulate, of several whorls, continuing the line of the spire. Sculpture of 3 or more spiral keels, broken into small and ill-defined tubercles, and crossed by transverse bars, making the whole strongly clathrate. Base excavate, the columella generally acuminate.

The elongate, turreted shell, the deep sutures, the relatively long whorls, and the clathrate sculpture make this large group of species easily recognizable. Most of the Peronian species which have now been transferred to *Clathropsis* are not so elongate as the Solanderian species, and some have small secondary keels between the main ones, a character also present in *C. impedita.*

In his list of Queensland Mollusca Hedley (1910) included *Cerithiopsis angasi* Semper, the type locality of which is Port Jackson. No further reference to this species from Queensland has been found in the literature, and it is quite probable that the record is based on one of the species of *Clathropsis* here discussed. *C. angasi* was originally described as *C. clathrata* Angas, but the name was rejected as preoccupied. It is doubtful if the species occurs in Queensland at all. Curiously enough, from the original description and figure it is not clathrate at all, and in the revised list of Peronian species it is now placed under *Socienna.*

CLATHROPSIS IMPEDITA, sp. nov.

Figs. 9 and 10

Shell elongated, turreted, thin, and translucent, colour pale yellow, with chocolate bands at the base of each whorl defining the sutures, base golden brown. Protoconch of 3½ smooth whorls, continuing the line of the spire, terminated by a faint varix. Mature whorls 7, relatively long, rounded, the sutures deeply impressed. Sculpture fine and delicate, the body whorl with 4 thin, sharp keels, with secondary spiral threads between, both overridden by numerous transverse cords, which rise above the main keels in very small, ill-defined tubercles. About 30 of these cords are on the body whorl; the others have rather less. The whole pattern is strongly clathrate. A 5th plain keel is on the base of the body whorl. Base slightly excavate. Aperture large, the outer margin thin and indented by the sculpture, canal short, wide and open. Columella narrow and anteriorly acuminate. Length 3·6 mm.

Locality.—Masthead I., Capricorn Group, Qld. (C. Hedley).

Remarks.—This beautiful little species is quite distinctive, and can readily be recognized by the colouring and delicate sculpture.

CLATHROPSIS MELLITA, sp. nov.

Fig. 11.

Shell of medium size, attenuate, turreted, colour a uniform honey-yellow. Protoconch not quite perfect in the type, 3 whorls only remaining, smooth, mature sculpture beginning abruptly, but no varix discernible. Mature whorls 9, increasing regularly, rounded, sutures deeply indented. Sculpture of 3 highly elevated, narrow keels, of which the uppermost 2 are the strongest, the lower keel weakest and just above the sutures and on the base of the body whorl. The transverse sculpture is strong, elevated cords, about 22 to the whorl, overriding the keels and continuing to the sutures, making the whole strongly clathrate. Base excavate. Aperture subquadrate, the outer lip thin and indented by the sculpture, canal shallow and rounded, columella narrow and slightly bent backwards, rounded anteriorly. Length 4·8 mm.

Locality.—Bundaberg, Qld., holotype and paratype (in Australian Museum, both numbered C20824).

Remarks.—The sculpture is distinctive, the two main keels with a weaker keel below at once separating this from all the other species discussed.

CLATHROPSIS TURRETA, sp. nov.

Figs. 12 and 13

Shell narrow and very attenuate, turreted, white. Protoconch in holotype incomplete, but another immature specimen has 4 whorls with no discernible varix. Mature whorls 9, rounded, the sutures very deeply impressed. Sculpture of 4 narrow, elevated keels, the uppermost the least prominent and becoming obsolete on the earlier whorls, a 5th plain keel on the base of the body whorl. The transverse sculpture is strong, consisting of sharp threads, about 18 to the whorl, overriding the keels and breaking them into small indistinct tubercles, the whole being strongly clathrate. Base excavate. Aperture subquadrate, the outer margin thin and indented by the sculpture, canal narrow, short, rounded, behind the columella. Columella short and broad, anteriorly oblique and acuminate. Length 4·5 mm.

Locality.—Masthead I., Capricorn Group, Qld. (C. Hedley), holotype and 3 paratypes.

Remarks.—This species generally resembles *C. mellita*, but can be readily separated by the presence of the extra keel. In addition to the type, specimens from other widely separated localities have slightly different facies, but the material is not in good enough condition to indicate whether there is more than 1 species or race. A specimen from Michaelmas Cay collected by T. Iredale is here figured for comparison (Fig. 13). This is also white, somewhat longer (5·7 mm) and broader, and has similar sculpture, but what remains of the protoconch is rather narrower, is yellow-brown, and has a horny texture. From the Hope Islands, still farther to the north, are specimens which are yellow in colour and smaller, and one has 8 whorls in a length of 3·7 mm. The protoconch is of 4 whorls. Another specimen, possibly not mature, has 6 whorls in a length of only 2·1 mm, and a protoconch of 3 whorls. Whether *C. turreta* is a variable species with a wide range, or whether it is one of a group of closely related races or species, it is as yet impossible to say.

Clathropsis maritima, sp. nov.

Fig. 14

Shell comparatively large, robust, elongate but not attenuate, turreted, colour golden brown, deeper on the topmost keel and in the suture. Protoconch in the holotype broken, but if specimens from Michaelmas Cay be the same species it has 4 smooth whorls, terminated by a varix. Mature whorls 9, increasing regularly, sutures deeply impressed. Sculpture of 3 prominent raised keels, the uppermost somewhat smaller than the others, separated by deep channels, a 4th keel on the base of the body whorl. The transverse sculpture is moderately strong, consisting of cords, about 20-22 to the whorl, which override the keels as small indistinct tubercles. Base excavate. Aperture subquadrate, outer margin thin and indented by the sculpture, canal short, rather narrow and rounded. Columella narrow and straight, anteriorly obliquely acuminate. Length 5·5 mm.

Locality.—Caloundra, Qld., shell sand (J. Laseron), holotype.

Remarks.—This is a broader and more robust species than any of the preceding, and cannot readily be confused with any of them. On the other hand there may be other and still undescribed species which come much closer. Four specimens from Michaelmas Cay well to the north and part of the Barrier Reef, none quite mature and somewhat variable in width, cannot be separated from *C. maritima* in sculpture and general form, but they are all pure white, and have slightly flatter spires. Another specimen from Lindeman I. is also white and differs also by having the small, rounded tubercles very well defined. Further material will possibly show that these are distinct species.

Clathropsis darwinensis, sp. nov.

Fig. 15

Shell small, conical, turreted, colour pale straw. Protoconch of 3 smooth whorls, terminated by a faint varix. Mature whorls 6 (the type may not be quite mature), increasing regularly, the sutures deeply indented. Base excavate. Sculpture of 3 well-raised keels, the uppermost much smaller than the others and absent on the earlier whorls, a 4th plain keel on the base of the body whorl. Transverse sculpture of raised cords, about 25 to the whorl, which barely override the keels without producing tubercles, the whole sculpture strongly clathrate. Aperture subquadrate, outer margin thin, indented by the sculpture. Columella narrow, slightly curved, anteriorly acuminate. Length 3 mm.

Locality.—Darwin (J. Laseron), holotype.

Remarks.—This is the broadest of all the species here described. In a species from a different zoogeographical province differences can naturally be expected, but actually there is no Solanderian or Peronian species with which it can be closely compared.

CLATHROPSIS THORNLEYANA, sp. nov.

Fig. 16.

Shell of medium size, attenuate, turreted, colour grey (may be faded). Protoconch rather stout, continuing the line of the spire, whorls 4, terminated by a varix. Mature whorls 7, increasing regularly, sutures deeply impressed. Sculpture strongly clathrate, spiral keels 3, the uppermost the smallest and barely visible on the earlier whorls, a 4th plain keel on the base of the body whorl. The keels are narrow, well raised, and sharply defined. They are overridden by narrow, sharp, transverse cords, about 16 to the whorl, of nearly equal value to the keels, and rising above them in small tubercles. The pits formed by the intersection of the keels and transverse cords are nearly square and sharply defined. Base excavate. Aperture and columella not quite perfect in the type, but apparently of the usual subquadrate shape, with the outer margin indented by the sculpture, the columella broad and straight. Length 4·2 mm.

Locality.—Holotype dredged, Port Curtis, Qld. (Miss G. Thornley, after whom the species is named).

Remarks.—This is nearest to *C. mellita*, but comparison beneath the microscope shows that the keels are lower and narrower than in *mellita*, and the transverse cords are fewer and do not override the keels to the same extent. In *mellita* also the lowermost keel is the smallest, while in *thornleyana* the uppermost is least.

Genus SYNTHOPSIS, gen. nov.

Type species *Synthopsis cylindrica*, sp. nov.

Small, rather broad shells of cylindrical form, of 6 or less relatively short whorls, the initial mature whorl comparatively large, the sutures indented, but the spire not turreted and slightly convex. Protoconch slender and delicate, its base less than the diameter of the summit of the mature shell. Sculpture of 3 keels, broken into indistinct tubercles and connected by transverse bars. Base excavate.

Synthopsis seems a natural genus, and includes a group of species with a distinct facies, occurring in the southern provinces as well as the north.

SYNTHOPSIS CYLINDRICA, sp. nov.

Fig. 17

Shell narrowly cylindrical, spire slightly convex with little taper, straw-coloured with a pure white protoconch. Protoconch slender, narrower than the summit of the mature shell, smooth, of 5½ whorls, terminated by a varix. Mature whorls 5, short, increasing slowly, the spire not restricted at the base, sutures deep. Base excavate. Sculpture of 3 spiral keels, the uppermost the smallest, separated by deep channels, a 4th keel on the base of the body whorl. Each keel rises into small irregular tubercles, about 22 to the whorl, connected from row to row by low threads, which are not prominent enough to produce a cancellation. Aperture subquadrate, the outer margin thin and indented by the sculpture, canal straight, fairly deep, and rounded. Columella fairly long, acuminate anteriorly. Length 3·2 mm.

Locality.—Michaelmas Cay, Qld. (T. Iredale), holotype.

Remarks.—A 2nd specimen from the same locality may be a more mature individual of the same species, or further material may show it to be distinct. It is white, with 7 whorls in a total length of 4 mm, the sculpture is similar, though the tubercular nature of the keels is not so distinct, and the last 2 whorls have very fine secondary keels between the main ones. The base is similar, but unfortunately the protoconch is broken, and its exact determination must for the time being be left in abeyance.

SYNTHOPSIS COLUMNA, sp. nov.

Fig. 18

Shell small, nearly cylindrical, the spire with only a slight taper, the holotype straw-coloured but other specimens ranging to brown. Protoconch of type imperfect, but the 1½ whorls remaining show it to be white and slender and terminated by a varix. Mature whorls 5, short, increasing gradually, the contour of the spire very slightly convex, not restricted at the base, the sutures deep and defined. Sculpture of 3 broad keels, the uppermost slightly narrower, separated by narrow channels, a 4th keel on the base of the body whorl. The keels are broken into large but not well-defined tubercles, about 17 to the whorl, and connected at their bases from row to row. Base excavate. Aperture subquadrate, the outer margin thin and not indented by the sculpture, canal straight, fairly deep and rounded. Columella broad, obliquely truncate anteriorly, and crossed by several fine threads. Length 2 mm.

Locality.—Masthead I., 17-20 fm (C. Hedley), holotype and 2 paratypes.

Remarks.—Compared with *S. cylindrica* this species has a different contour, it is smaller, and the sculpture is much coarser, the tubercles larger and fewer.

SYNTHOPSIS COLUMNA INFANS, subsp. nov.

Fig. 19

From the Masthead I. dredgings several specimens were sorted which were readily separated from *S. columna* by being smaller, relatively broader, and with 1 whorl less. They do not seem to be the young of the typical *columna*, for the expanded outer margin of the aperture is not indented by the sculpture, which generally indicates full maturity. The sculpture is, however, nearly identical, as is the columella with its transverse threads. The length of the specimen figured is 1·6 mm. Perfect protoconchs of the 2 forms might show that they are distinct species, but in view of the constancy of the other differences it seems advisable to give the smaller shell at least a new subspecific name.

SYNTHOPSIS DEMISSA, sp. nov.

Fig. 20

Shell small, cylindrical, spire slightly convex, colour straw. Protoconch slender, of same colour as the mature shell, 4½ whorls, terminated by a varix. Mature whorls

5, short, increasing slowly, initial whorl relatively large, penultimate whorl as large as the body whorl, sutures impressed. Sculpture of low relief, consisting of 3 narrow spiral keels, the uppermost smaller than the others, a 4th keel on the base of the body whorl, crossed by narrow transverse cords, about 13 to the whorl, which rise above the keels in ill-defined, relatively small tubercles. The whole is shallowly cancellate. Base excavate. Aperture subquadrate, outer margin thin and slightly expanded, not indented by the sculpture, canal fairly deep and wide, straight. Columella broad, anteriorly obliquely truncate. Length 2·4 mm.

Locality.—Masthead I., 17-20 fm (C. Hedley), holotype.

Remarks.—Compared with *S. columna* the general form is similar, but the sculpture is of much lower relief, the tubercles are very small and farther apart, and the columella is smooth.

SYNTHOPSIS RADIX, sp. nov.

Fig. 21

Shell small, broadly cylindrical, spire slightly convex, contracted towards the summit but the 1st whorl still comparatively large, the penultimate whorl nearly as large as the body whorl, white and translucent. Protoconch white and porcellanous, fairly stout, of 4½ whorls, the last 2 slightly swollen, terminated by an oblique varix. Mature whorls 6, short, the last 3 practically equal, sutures indented. Sculpture rugged, but not clearly defined, of 3 broad spiral keels, a 4th on the base of the body whorl, the uppermost the smaller, particularly in the early whorls. The keels are broken into prominent but irregularly shaped tubercles, about 20 to the whorl, which are connected, row to row, by indistinct, low, transverse threads. Base excavate. Aperture subquadrate, but in the holotype, which is probably nearly but not quite mature, it is not fully developed and is short, and the outer margin is indented by the sculpture. Columella broad and truncate. Length 3·2 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype.

Remarks.—This is the broadest of all the species of *Synthopsis* here discussed, and there are also distinctive differences in contour, colour, sculpture, and the form of the columella.

Genus CONCILIOPSIS, gen. nov.

Type species *Conciliopsis carrota*, sp. nov.

One Queensland species amongst those so far examined has such a distinctive facies that it will not fit into any of the other groups here proposed. The form is best described as that of an inverted carrot, broad at the base, with a convex spire, and tapering to a fine apex. The protoconch is slender and many-whorled. The sutures are well defined but not deeply impressed. There are 6 or 7 short mature whorls, and the sculpture is of 3 rows of sharply defined hemispherical tubercles, much more defined than in *Synthopsis*, which is perhaps the most closely related of the other genera.

CONCILIOPSIS CARROTA, sp. nov.

Fig. 22

Shell of medium size, in form like an inverted carrot, broad and slightly restricted at the base, attenuate towards the summit, colour straw with a colourless protoconch. Protoconch slender, smooth, and transparent, of 5 whorls, terminated by a slight varix. Mature whorls 7, short, sides flat, sutures distinct but not deeply impressed. Sculpture of 3 equal rows of large, well-defined, rounded tubercles, about 18 to the whorl, separated narrowly from each other but joined at the base with those of the adjacent rows, a 4th plain keel on the base of the body whorl. Base excavate. Aperture subquadrate, outer margin indented by the sculpture, canal short, straight, and rounded. Columella short, slightly curved, oblique and acuminate anteriorly. Length 3·8 mm.

Locality.—Eclipse I., Qld., holotype (in Australian Museum, C7273).

Remarks.—The carrot-like form and large clear tubercles should make the future recognition of this species easy. It is possible that the type is not quite mature, but from the restriction at the base it is doubtful that it could attain more than another half-whorl.

Genus SPECULA Finlay

Specula Finlay, 1926, Trans. Proc. N.Z. Inst. **57**: 382. Cotton, 1951, Rec. S. Aust. Mus. **9**(4): 385.

Type species *Cerithiopsis styliformis* Suter (Finlay 1926, p. 382).

Shell very similar in form and sculpture to *Synthopsis*, with a relatively short, cylindrical spire of about 6 whorls, sculpture of 3 rows of tubercles, but with a short inflated protoconch.

The protoconch can be considered here as having generic but not phylogenetic value, as marking some definite phase in the life history of the larval form. It is curious that a very similar protoconch is found in other quite unrelated families, notably in *Paraguraleus* in the Turridae and in some of the Rissoidae, but its significance is not yet understood.

SPECULA QUEENSLANDICA, sp. nov.

Figs. 23 and 24

Shell small, subcylindrical, spire slightly convex and slightly restricted at the base, dull yellow (may be a faded brown). Protoconch of 2 inflated whorls, smooth, terminated by a slight, curved varix, the nucleus large and infolded. Mature whorls 5, short, sides nearly flat, but sutures distinct and impressed, initial mature whorl relatively large. Sculpture of 3 rows, with a 4th on the body whorl, of large rounded tubercles, about 16 to the whorl, rising from broad keels, so close that the tubercles are connected at their bases from row to row. On the 1st mature whorl the topmost row is smaller than the others, otherwise they are all subequal. Base not excavate, and bearing a single, thin plain keel. Aperture subquadrate, outer margin not quite perfect in the type, but evidently indented by the sculpture. Columella short, straight, broad, anteriorly obliquely truncate. Length 2·4 mm.

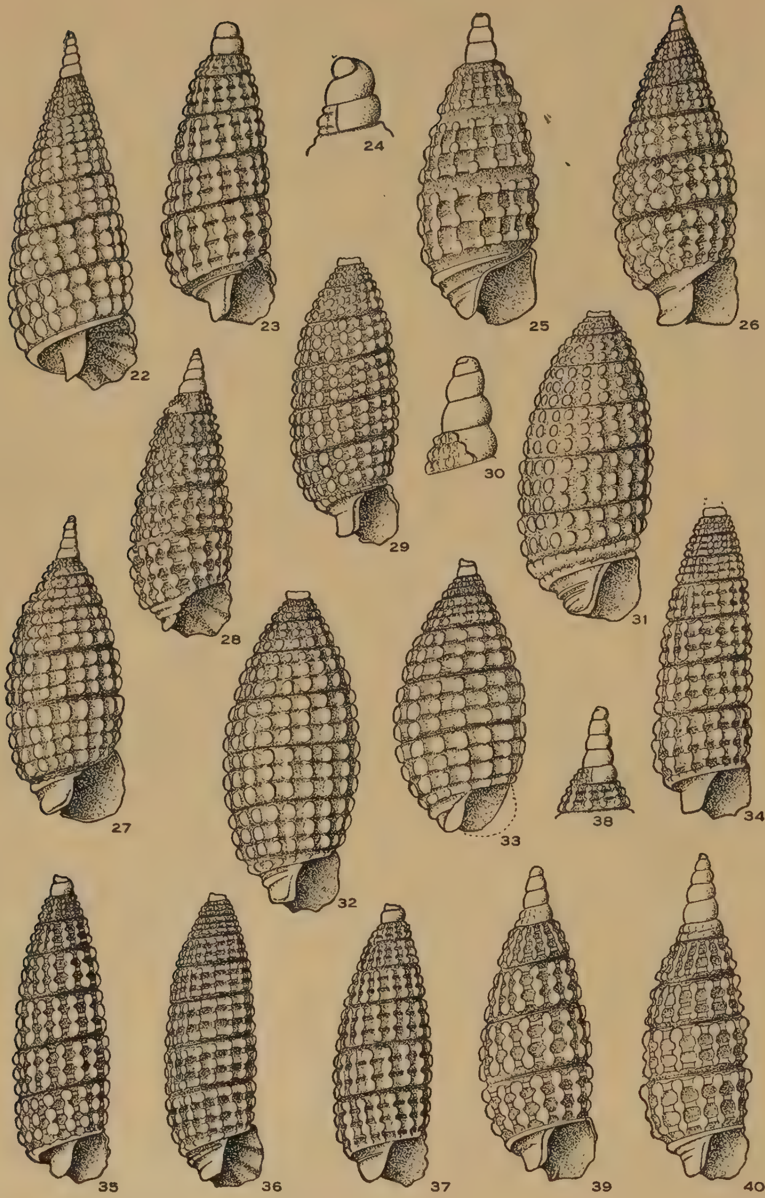


Fig. 22.—*Conciliopsis carrota*, sp. nov. Holotype. × 12. Fig. 23.—*Specula queenslandica*, sp. nov. Holotype. × 16. Fig. 24.—*S. queenslandica*. Protoconch. Fig. 25.—*Joculator ridicula* (Watson). After Watson. × 28·5. Fig. 26.—*J. continens*, sp. nov. Holotype. × 11. Fig. 27.—*J. subula*, sp. nov. Holotype. × 14·5. Fig. 28.—*J. melania*, sp. nov. Holotype. × 15·5. Fig. 29.—*J. varians*, sp. nov. Holotype. × 12. Fig. 30.—*J. varians*. Another specimen, protoconch. Fig. 31.—*J. varians*. Variation. × 15·5. Fig. 32.—*J. albordina*, sp. nov. Holotype. × 11. Fig. 33.—*J. ovata*, sp. nov. Holotype. × 16. Fig. 34.—*J. tomacula*, sp. nov. Holotype. × 15·5. Fig. 35.—*J. tomacula*. Variation. × 18·5. Fig. 36.—*J. tomacula negrita*, subsp. nov. Holotype. × 11·5. Fig. 37.—*J. tomacula propinqua*, subsp. nov. Holotype. × 14·5. Fig. 38.—*J. tomacula propinqua*. Protoconch. Fig. 39.—*J. tribulationis* (Hedley). Paratype. × 19. Fig. 40.—*J. minima*, sp. nov. Holotype. × 21·5.

Locality.—Hope Is., 5-10 fm (C. Hedley), holotype and 1 paratype.

Remarks.—In general form and sculpture this is very close to *Synthopsis columna*, but it can be at once distinguished in perfect specimens, both specifically and generically, by the protoconch.

Genus JOCULATOR Hedley

Joculator Hedley, 1909, Proc. Linn. Soc. N.S.W. **34**: 442. Cotton, 1951, Rec. S. Aust. Mus. **9**(4): 389. Laseron, 1951, Aust. Zool. **11**(4): 362.

Type species *Cerithiopsis ridicula* Watson (Hedley 1909, p. 442).

Shells small, with bulbous or ovate contours, restricted at the base, which is rarely excavate but generally bears 1 or more spiral ribs; the columella broad and truncate, the mature aperture with a thin expanded outer margin not indented by the sculpture. The sculpture consists of 3 rows of rounded tubercles on each whorl, the whorls separated by shallow sutures which are generally distinct, but are sometimes hard to discern. The protoconch is smooth, slender, and of many whorls, and is easily broken, so that complete specimens are hard to obtain.

Though originally proposed as a subgenus of *Cerithiopsis* investigation shows *Joculator* to be a large and complex group with many species, most of which seem to have a small geographical range. On the whole the species are not difficult to separate, though worn and imperfect material is at times impossible to classify. Specimens are never abundant, and one of the difficulties is that long series are seldom available to determine the extent of individual variation. From the limited data the tentative conclusion is drawn that most of the species are reasonably constant, but that a few are variable within limits in both size and shape. Where there is a decided colour pattern this can be taken as constant and a good character for quick recognition. The slight variability in shape is due to unequal growth in the median whorls which may give either an oval or a cylindrical contour to the spire. The protoconch is a very valuable character, but it is so delicate that it is often broken, or it may be cast at an early stage even when alive. Where a number of specimens occur from one locality it has been found advisable to study only those with complete protoconchs, but to have done this throughout would have meant the elimination of many otherwise distinctive species. The form of the columella in fully mature individuals is a useful character, but it varies according to the age of the shell. After the growth of the spire ceases and the aperture is fully formed, the margin of the columella continues to thicken, it becomes blunter anteriorly, and a distinct ridge develops here and adjacent to the aperture. In nearly all the species sculpture becomes obsolete towards maturity, and the outer margin of the aperture expands and becomes sinuous posteriorly.

Within *Joculator* as defined are many small groups of closely related species, whose characters are not sufficiently divergent to justify further generic or subgeneric division. The type of *Joculator* is a short, oval shell of only 3 whorls with broad, shallow sutures. There is another group, however, of larger shells, typified by *J. albordina*, with 6 or 7 whorls and narrow sutures. Still another group includes much narrower shells which are quite cylindrical in mid section. These are typified by *J. tomacula*. Nevertheless new generic names are proposed for two groups with distinctive characters: *Horologica* with only 2 unequal rows of tubercles to the whorl, and *Potenatomus* for minute shells with short, bulbous protoconchs.

JOCULATOR RIDICULA (Watson)

Fig. 25 (after Watson)

Cerithiopsis ridicula Watson, 1886, *Challenger Zool. Rep.* **15**: 528, pl. 38, fig. 1.

The type locality is 8 fm, coral mud, off Wednesday I., Torres Strait, and the dimensions are: height, 0·055 in. (*c.* 1·4 mm); breadth, 0·023 in. (*c.* 0·6 mm).

The type is in the British Museum and thus not available to the author, but from the description it is minute, with a 4-whorled protoconch and only 3 mature whorls, the suture distinct, each whorl with 3 rows of small tubercles, about 20 to the whorl, and connected, row to row, by transverse cords. The colour is deep brown. This description does not fit any of the other species here examined.

JOCULATOR CONTINENS, sp. nov.

Fig. 26

Shell large for the genus, very inflated, bottle-shaped, the greatest width about one-third from the base, colour deep brown, almost black. Protoconch small and slender, smooth and brown, of 3 whorls, terminated by a varix. Mature whorls 7, restricted towards the base which is slightly excavate, the sutures shallow but defined. Sculpture of equal, broad, spiral keels, 3 to the whorl, with a 4th on the base of the body whorl, bearing large rounded tubercles, about 19 to the whorl, connected at their bases by low ridges to the adjoining rows. A small ridge is on the base, just above the columella. Aperture subquadrate, the outer lip expanded, thin and sinuous, canal rounded and open, behind the columella. Columella broad and truncate, anteriorly bent backwards, a thin ridge bordering the anterior margin and the aperture, its surface slightly puckered. Length 3·9 mm.

Locality.—Bowen, Qld., crawling with other species on sponges on the underside of rocks (J. Laseron), holotype and 2 paratypes.

Remarks.—This is the first of several species with 5-7 whorls and with the sutures defined. Apart from other characters its comparatively large size and the very small slender protoconch are good recognition points.

JOCULATOR SUBULA, sp. nov.

Fig. 27

Shell smaller than *J. continens*, very inflated, barrel-shaped, the greatest width about the centre, colour deep brown, almost black. Protoconch slender, tilted, brown, and smooth, of 5½ whorls, terminated by a varix. Mature whorls 6, the body whorl restricted at the base, the sutures shallow and just distinguishable, base not excavate. Sculpture of 3 subequal rows of large rounded tubercles on each whorl, about 18 to the whorl, a 4th row on the base of the body whorl, and a 5th small tuberculous keel just above the columella. The tubercles are very close transversely, practically touching from row to row. Aperture ovate, outer margin thin and expanded, slightly sinuous, canal rounded and open, behind the columella.

Columella short, very broad, rounded anteriorly, bordered by a narrow ridge anteriorly and on the margin of the aperture. Length 2·8 mm.

Locality.—The holotype was found with *J. continens* on sponges below rocks, Bowen, Qld. (J. Laseron).

Remarks.—This is very close in form and sculpture to *J. continens*, but is much smaller and has an entirely different protoconch.

JOCULATOR MELANIA, sp. nov.

Fig. 28

Shell small, inflated, but narrower than the preceding 2 species, bottle-shaped, colour deep brown, almost black. Protoconch comparatively large, conical, broad at the base but tapering to an acute apex, of 4½ whorls, smooth, and pale brown. Mature whorls 5, sutures distinguishable but not clearly defined, the body whorl restricted at the base which is not excavate. Sculpture of 3 well-defined keels, 4 on the body whorl, which rise into well-defined but not large, round tubercles, about 17 to the whorl. These are connected, row to row, by thin transverse threads, not always easy to discern. Aperture rounded, outer margin expanded, slightly sinuous, canal rounded and semicircular, open. Columella short, narrowed anteriorly, rather variable, the holotype bearing 2 smooth keels, another specimen with 1 only. Length 2·5 mm.

Locality.—Bowen, Qld., crawling on sponges beneath rocks (J. Laseron), holotype and 3 paratypes.

Remarks.—This is one of 4 species found associated together at Bowen. All were of the same colour, and were not at first easy to separate. *J. melania* is indeed very close to *J. subula*, but is smaller and rather narrower, the tubercles are smaller, and the keels are more defined. The essential difference is, however, in the protoconch, that in *melania* being conical and not subulate, and broader at the base.

JOCULATOR VARIANS, sp. nov.

Figs. 29-31

Shell of medium size for the genus, inflated, barrel-shaped, the 3 median whorls almost equal in size, colour grey-yellow (may be faded), protoconch white. The protoconch, drawn from a specimen other than the type, is relatively stout, tilted, pure white, of 3½ whorls, terminated by an oblique varix. Mature whorls 6, short, the 3 median whorls nearly equal, the body whorl restricted at the base which is not excavate, sutures shallow but defined. Sculpture of 3 equal well-defined keels to each whorl, a 4th on the base of the body whorl, which rise into fairly large, round tubercles, close together and about 20 to the whorl. Transversely these are also close together, practically touching at their bases. Aperture subquadrate, outer margin expanded, thin and slightly sinuous, canal circular, about one-fourth open, behind the columella. Columella short, broad, truncate anteriorly, a narrow keel just above it, the anterior margin and that adjoining the aperture with a narrow ridge. Length 3 mm.

Localities.—Hope Is., Qld., 5-10 fm (C. Hedley), holotype and 1 paratype; Heron I., under coral blocks (J. Laseron); Michaelmas Cay (T. Iredale).

Remarks.—If all the identifications are correct, this species has a much wider range than usual, but is also somewhat variable in form and size. Specimens from all the above localities have the same equal 3 median whorls, which makes this portion of the spire cylindrical and gives an easily recognizable facies. None of the Heron I. specimens have perfect protoconchs, only enough to show that these also are pure white. The mature shells are deep brown and slightly smaller, but otherwise conform to the description. Specimens from Michaelmas Cay may be another species, but unfortunately none has a protoconch to decide this issue. They are deep brown in colour, and there are differences in the columella. One is here figured for comparison (Fig. 31), its length without a protoconch being 2·6 mm.

Compared with *J. subula*, *J. varians* has a different contour, and the protoconch is also different.

JOCULATOR ALBORDINA, sp. nov.

Fig. 32

Shell comparatively large, very inflated, ovate, the greatest width about the centre, the penultimate whorl slightly, and the body whorl greatly contracted at the base, colour pattern distinctive, the upper row of tubercles pure white, the lower rows a pale honey. Protoconch unknown. Mature whorls 6, the 4th whorl the largest, the sutures not distinct but determinable by the colour pattern, the base not excavate. Sculpture of 3 low, wide, narrowly separated keels, a 4th on the base of the body whorl, from which rise large, regularly rounded tubercles, about 20 to the whorl. Another plain keel is on the base, just above the columella. Aperture subquadrate, relatively small, outer margin expanded, thin and slightly sinuous, the canal semicircular and open, behind the columella. Columella short and anteriorly truncate, bordered anteriorly and adjacent to the aperture by a ridge. Length 3·8 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype and 1 paratype.

Remarks.—In size and sculpture this approaches *J. continens*, but comparison of the figures shows quite different contours. *J. albordina* also has a smaller aperture, a different columella, and larger and more defined tubercles. The colour is also quite distinctive.

JOCULATOR OVATA, sp. nov.

Fig. 33

Shell small, broadly ovate, very inflated, width more than half the length, colour partially faded but sufficiently preserved to show a similar pattern to that of *J. albordina*, the upper row of tubercles white, the others a pale buff. Protoconch incomplete, only 1½ whorls remaining, but sufficient to show it to be slender and probably of several whorls. Mature whorls 5, the penultimate the largest, separated by narrow but distinct sutures, the body whorl greatly contracted below, the base not excavate. Sculpture of 3 well-defined, equal, broad, low spiral keels, a 4th on the base of the body whorl, separated by narrow channels, the keels rising into large, rather irregular, and sometimes almost square tubercles, about their own width apart, and about 14 to the whorl. Transversely the tubercles almost touch those in the adjacent rows. Aperture of the type with the outer margin broken, but it is small. Columella short and broad, bearing a single large ridge, and covered nearly completely by a wide plate of callus. Length 2·2 mm.

Locality.—Hope Is., 5-10 fm (C. Hedley), holotype.

Remarks.—A new species is here proposed on a single slightly imperfect specimen, but its characters are such that future recognition should be easy. It is the broadest of any species so far examined, and the regular ovate contour, the large irregular tubercles, and the columella are distinctive. The colour pattern is also distinctive, resembling generally that of *J. albordina*, from which all its other characters separate it.

JOCULATOR TOMACULA, sp. nov.

Figs. 34 and 35

Shell elongate, cylindrical, spire with very little taper, contracted at the summit and very slightly at the base, colour yellowish, probably faded. Protoconch of type broken, with only 1 whorl remaining, but apparently slender. Mature whorls 7, the last 4 nearly equal, sutures shallow but distinct, the base slightly excavate. Sculpture of 3 equal keels, a 4th on the base of the body whorl, broken into medium-sized tubercles, about 16 to the whorl, and connected row to row by low, short bars. Aperture subquadrate, outer margin thin and nearly straight, canal semicircular and rather deep. Columella broad and straight, anteriorly obliquely truncate. Length 2·7 mm.

Localities.—Michaelmas Cay (T. Iredale), holotype; Masthead I. (C. Hedley).

Remarks.—A number of these small, elongate, cylindrical shells occur in widely separate localities, but the material is generally in rather poor condition for accurate comparison. Better material will probably show that there are several species. Specimens from Masthead I. have only 6 whorls, and are rather smaller than the type. One is here figured for comparison (Fig. 35). It is 2·2 mm in length. Other specimens from Hope Is. and from Bowen show sufficient differences to discuss separately, and they are given new racial names which may later be found to be fully specific. The protoconch, when found, may provide the clue.

JOCULATOR TOMACULA NEGRITA, subsp. nov.

Fig. 36

Specimens from Bowen collected by J. Laseron were found crawling on sponges beneath rocks, associated with species of *Joculator* already described. They correspond in general characters with *J. tomacula* but are larger, the holotype illustrated being 3·3 mm in length; they are deep brown and almost black in colour, have a more expanded aperture, and have a small tuberculate keel just above the columella. The body whorl is also rather more contracted at the base, which gives a different contour to the spire. They are here provisionally proposed as a geographical race of *J. tomacula*, distinctive of the mainland as compared with the Barrier Reef, but further material will probably show that the difference is specific.

JOCULATOR TOMACULA PROPINQUA, subsp. nov.

Figs. 37 and 38

From material collected by the late Charles Hedley from 5-10 fm, Hope Is., 1 mature specimen without a protoconch and 2 juveniles with protoconchs were sorted, which conform in sculpture and aperture to the typical *J. tomacula* but show other differences to justify at least subspecific rank. The main difference is in the contour of the spire, which is definitely broader and more convex, giving the whole quite a different facies. The protoconch is slender, of 5 whorls, terminated by a varix, and its colour is pure white, in contrast with the faded grey of the shell itself. The length of the holotype illustrated is 2·5 mm.

JOCULATOR TRIBULATIONIS (Hedley)

Fig. 39

Cerithiopsis (Joculator) tribulationis Hedley, 1909, Proc. Linn. Soc. N.S.W. **34**: 441, pl. 40, fig. 57.

The type locality is 5-10 fm, Hope Is., where specimens are fairly common. That figured is from this series, and is 2·1 mm in length. Specimens are all apparently faded and are cinnamon in colour, but the protoconch is white. There is a slight variation in shape; the type and others are slightly more cylindrical than that figured; some are also rather stouter, but the variation is within narrow limits. Hedley in his description gives the number of whorls as 6, but his figure shows only 5, and the usual number in mature specimens is from 4½ to 5. Worn specimens show a distinctly clathrate pattern.

Of all the species examined this is the closest to the type species *J. ridicula*, to which it is evidently closely related. It has, however, more whorls, and a different columella.

JOCULATOR MINIMA, sp. nov.

Fig. 40

A small, slightly worn specimen, sorted out from the material from 5-10 fm, Hope Is., is so close to *J. tribulationis* that it could be taken for that species were it not for the protoconch. It has 4½ mature whorls, the sutures are well defined, and a description of sculpture, aperture, and base is identical with *tribulationis*, except that it is a trifle narrower and the upper row of tubercles are slightly larger than the others. The protoconch is, however, relatively much larger, has 5½ whorls instead of 3½, is wider at the base, and is more acuminate at the apex. The length of the whole shell is 1·9 mm. It is possible that 1 or 2 of the narrower specimens without protoconchs taken as *tribulationis* are really this species, but here the complete protoconch is absolutely necessary to be sure of specific identification.

Genus HOROLOGICA, gen. nov.

Type species *Horologica bicolor*, sp. nov.

Like *Joculator*, but with only 2 rows of tubercles to each whorl, the upper row generally the larger. The tubercles are also generally connected from row to row by short bars, which gives each pair the appearance of an hour-glass. In most of the species the sutures are ill defined, and it is at times difficult to determine the number of whorls, particularly when the 2 rows of tubercles are nearly equal in size. A peculiarity noted in some species is that in the penultimate whorl the upper row of tubercles become increasingly elongated, and then commence to divide into 2 rows, the fission becoming complete in the body whorl, to ultimately form 4 nearly equal rows of tubercles including the additional one generally present on the base.

HOROLOGICA BICOLOR, sp. nov.

Fig. 41

Shell relatively large, cylindro-conical, restricted at the base, solid, colour cinnamon, the upper keels on each whorl and the columella chocolate. Protoconch unknown. Mature whorls 8, the sutures very narrow but defined, base slightly excavate. Sculpture of 2 wide keels to each whorl, the lower the narrower and well separated. Above the keels rise the tubercles, transversely oval in shape, the upper row the largest, about 16 to the whorl. These are connected row to row by transverse bars, giving each pair an hour-glass appearance. On the body whorl the tubercles of the upper row divide medially into 2 rows of smaller tubercles, almost touching each other, while on the lower keel the tubercles are almost obsolete. Below this on the base is still another keel, which is only slightly indented. Aperture nearly square, the outer margin expanded and nearly straight, the canal round and deep, behind the columella. Columella broad and straight, obliquely truncate anteriorly, with a narrow ridge adjoining the aperture. Length 3·2 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype and 1 paratype.

Remarks.—This species has been chosen as the type of *Horologica* in spite of the absence of a protoconch, as its peculiar sculpture is typical. Its distinctive colour pattern should make its future recognition easy.

HOROLOGICA ALBINO, sp. nov.

Fig. 42

Shell relatively large, bottle-shaped, early whorls slender, swollen below, body whorl restricted at base, colour pure white, cinnamon on base. Protoconch not quite perfect, 3 whorls remaining, slender and columnar. Mature whorls 7, short, sutures narrow but defined. Sculpture of 2 rows of tubercles on each whorl, the upper row larger and elongated, about 16 to the whorl. The rows are well separated, and the tubercles are connected, row to row, as in *H. bicolor*. On the body whorl, each tubercle of the upper row is beginning progressively to divide medially into 2 rows, so that a 3rd row would ultimately be formed. Another partially tuberculate keel is on the base, which is slightly excavate. Aperture subquadrate, the outer margin expanded slightly and sinuate near the suture, canal semicircular. Columella broad, rounded anteriorly, 1 thin ridge just above it, and a narrow ridge on its anterior margin and adjacent to the aperture. Length 3·5 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype.

Remarks.—This resembles *H. bicolor* in the sculpture, but the 2 species have quite different contours, and there are also differences in the apertures and columellas. The colour also is a good guide.

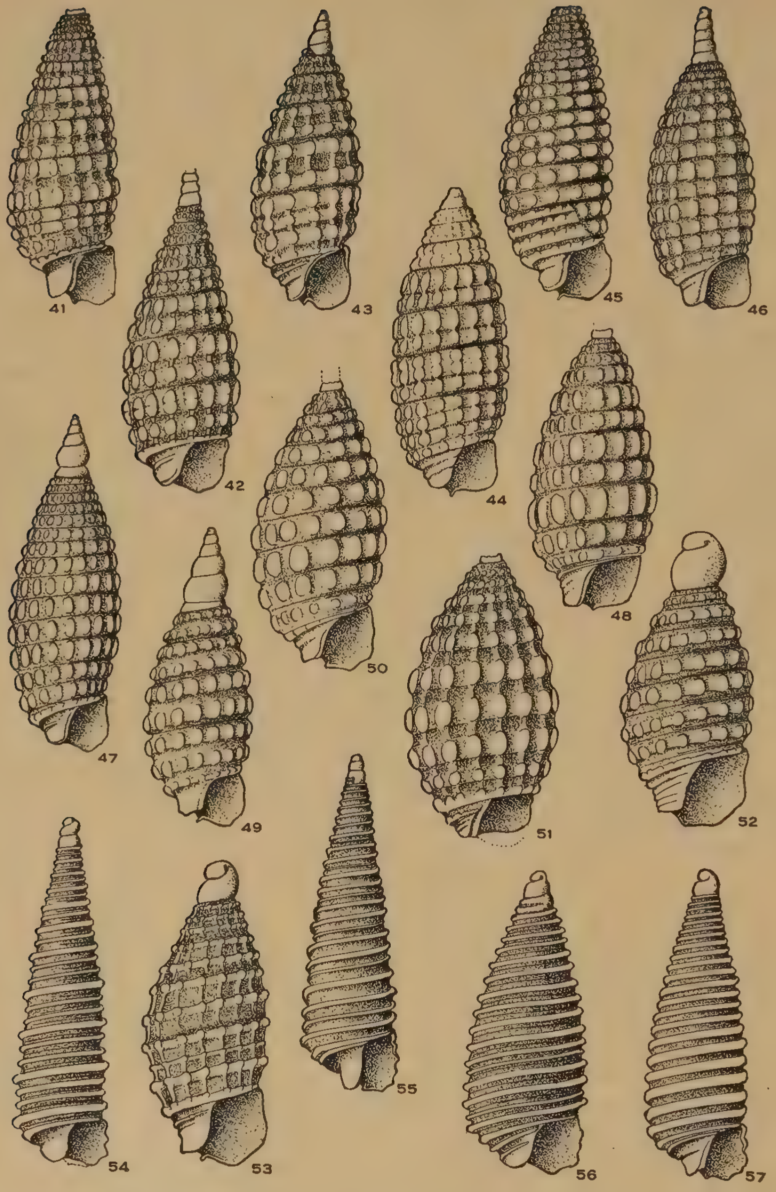


Fig. 41.—*Horologica bicolor*, sp. nov. Holotype. × 12. Fig. 42.—*H. albino*, sp. nov. Holotype. × 12. Fig. 43.—*H. bipartita*, sp. nov. Holotype. × 11. Fig. 44.—*H. purpurea*, sp. nov. Holotype. × 11. Fig. 45.—*Horologica* sp. × 11. Fig. 46.—*H. westiana* (Hedley). Paratype. × 15·5. Fig. 47.—*H. minareta*, sp. nov. Holotype. × 16. Fig. 48.—*H. telegraphica* (Hedley). Paratype. × 20. Fig. 49.—*H. macrocephala*, sp. nov. Holotype. × 21. Fig. 50.—*H. pinea* (Hedley). Paratype. × 18·5. Fig. 51.—*H. pinea nigrophyla*, subsp. nov. Holotype. × 21. Fig. 52.—*Potenatomus caputumere*, sp. nov. Holotype. × 42. Fig. 53.—*P. secundus*, sp. nov. Holotype. × 28·5. Fig. 54.—*Notoseila iredalei*, sp. nov. Holotype. × 9. Fig. 55.—*N. capricornia*, sp. nov. Holotype. × 8·5. Fig. 56.—*Paraseila heronensis* Laseron. Paratype. × 8·5. Fig. 57.—*P. ampulla*, sp. nov. Holotype. × 12.

HOROLOGICA BIPARTITA, sp. nov.

Fig. 43

Shell small, bottle-shaped, inflated, restricted at the base, colour deep brown, almost black. Protoconch white at apex, deepening at base, slender, tapering to an acute apex, of 4½ whorls, terminated by a varix. Mature whorls 5, short, body whorl relatively long, contracted below, sutures distinct, narrow but fairly deep. Sculpture of 2 broad keels, widely separated, above which rise the large, round, well-defined tubercles, about 13 to the whorl. The tubercles of each row are practically equal in size, and are connected, row to row, by narrow and ill-defined ridges. On the body whorl a 3rd row of tubercles has progressively developed, not by median fission but by an enlargement of the lower part of each tubercle of the top row, the new tubercles becoming larger until they are nearly the same size as the others. Another partially tuberculate keel is on the base of the body whorl, and 2 more plain keels just above the columella. Aperture subquadrate, outer margin expanded, sinuous near the suture, canal semicircular, behind the columella. Columella short, narrow, rounded anteriorly, a ridge bordering its anterior margin and adjacent to the aperture. Length 2·7 mm.

Locality.—Bowen, Qld., crawling on sponge beneath rocks (J. Laseron), holotype.

Remarks.—This species differs from both the preceding species by being smaller, with 2 fewer whorls; having a slightly different shape and a different colour; with the 2 rows of tubercles farther apart; with the tubercles larger, rounder, and fewer; and the growth of a new row of tubercles is achieved by a different method.

HOROLOGICA PURPUREA, sp. nov.

Fig. 44

The largest of the genus known, shell cylindrical and inflated, the last 4 whorls nearly equal, the summit tapering rapidly, the body whorl contracted below, colour bright purple, but the summit of the type corroded and white. Protoconch unknown. Mature whorls about 9, the sutures narrow but clearly defined. Sculpture of 2 rows of large tubercles, about 16 to the whorl, the uppermost the largest and elongate, connected by very short bars to the row beneath. On the penultimate whorl the upper row of tubercles are beginning to divide, and the fission is complete on the body whorl, making an additional row, with a 4th on the base. Base not excavate, bearing an additional small plain keel just above the columella. Columella very short, broad, and rounded anteriorly. Aperture subquadrate, the outer margin expanded and slightly sinuous, canal rounded, behind the columella. Length 3·7 mm.

Locality.—Heron I. (J. Laseron), holotype.

Remarks.—Compared with the species already discussed *H. purpurea* is larger and relatively broader, has a different shape, and has the two rows of tubercles closer to each other. It is probable either that there is more than one race of this species or that there are still undescribed but closely related species. Two imperfect specimens from Bowen match the type in colour and sculpture, but are slightly smaller and relatively narrower. Yet another specimen from Hope Is. is still smaller, only 2·9 mm in length, is also narrower, but is otherwise identical. This has one whorl of the protoconch remaining, showing it to be white and slender.

Horologica sp.

Fig. 45

A single imperfect specimen, sorted from the Hope Is. material collected by C. Hedley, is almost certainly an undescribed species; but more material is needed before it is given a name. It is therefore merely figured and recorded for future reference. It is white, large, 3·5 mm in length, cylindro-conical in shape, with about 9 mature whorls, the sutures barely distinguishable. The sculpture consists of 2 nearly equal rows of large tubercles, about 14 to the whorl, the tubercles of irregular shape and slightly elongated in a spiral direction. A curious feature of this specimen is that just as the body whorl was forming it was evidently broken but continued to grow, 3 low, only partially tuberculate keels taking the place of the 2 previous rows of large tubercles. In spite of this the aperture was perfectly formed, and corresponds to the usual type.

Horologica westiana (Hedley)

Fig. 46

Joculator westiana Hedley, 1909, Proc. Linn. Soc. N.S.W. **34**: 442, pl. 40, fig. 58.

The specimen figured came from the type locality, 5-10 fm, Hope Is., and is 2·5 mm long, compared with the type, 2·35 mm. It is the 1st of several species which are all small, under 3 mm in length, and in which the sutures are hardly distinguishable, so that the number of whorls is hard to determine. The number is generally from 5 to 6. The colour is given as ochraceous, but most of the specimens are faded. The 2 rows of tubercles in the earlier whorls are nearly equal in size, but in the later whorls the upper row become elongate, and on the body whorl divide into 2 rows, as in species previously described. The protoconch is slender and subulate, with 5½ whorls.

Horologica minareta, sp. nov.

Fig. 47

Shell small, bottle-shaped, not greatly inflated, colour of holotype a uniform golden yellow, another specimen faded to a dull buff. Protoconch relatively large, of 5½ whorls, shaped like an eastern minaret, its penultimate whorl swollen, the earlier whorls tapering to an acute apex. Mature whorls about 7, the sutures hard to distinguish, the penultimate whorl the largest, the body whorl contracted at the base which is slightly excavate. Sculpture of 2 rows of large tubercles axially elongate, about 16 to the whorl, the rows nearly touching and nearly equal in size. A small indented keel is on the base of the body whorl, and another thin smooth keel just above the columella. Aperture small, subquadrate, outer margin expanded, thin and sinuous, canal small and rounded. Columella short and broad, rounded anteriorly, a thin ridge on its anterior edge and bordering the aperture. Length 2·8 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype and 1 paratype.

Remarks.—This is very close to *H. westiana*, and its separation is based chiefly on the protoconch, which though it has the same number of whorls is of quite a different shape. It is also longer and narrower than *westiana* and has more whorls, and the 2 rows of tubercles are uniformly nearer equal in size.

HOROLOGICA TELEGRAPHICA (Hedley)

Fig. 48

Joculator telegraphica Hedley, 1909, Proc. Linn. Soc. N.S.W. **34**: 441, pl. 40, fig. 56.

The specimen figured is from the type locality, 5-10 fm, Hope Is., and its length is 1·8 mm compared with 2·1 mm for the type. It is a small, brown, inflated species, with about 5 whorls. The tubercles are large, the upper row elongate and about twice the size of those in the lower row. The sutures are ill defined. The protoconch is unknown.

HOROLOGICA MACROCEPHALA, sp. nov.

Fig. 49.

Shell small, ovate, not greatly inflated, the penultimate whorl the largest, body whorl contracted at base, colour golden yellow. Protoconch comparatively very large, nearly one-third of total length, its penultimate whorl swollen, tapering above to an acute apex. Mature whorls 4, sutures barely defined, base slightly excavate. Sculpture of 2 rows of tubercles, about 16 to the whorl, the rows nearly equal in size, separated from each other by shallow furrows rather wider than the sutures, very faint transverse cross bars connecting the tubercles, row to row. Aperture subquadrate, the outer margin expanded and slightly sinuous, canal small and rounded, behind the columella. Columella broad and obliquely truncate anteriorly, its corner truncate behind, a slight ridge bordering the margin of the aperture. Length 1·9 mm.

Localities.—Darwin, N.T. (J. Laseron), holotype; Christmas I., Indian Ocean, 100 fm (T. Iredale).

Remarks.—The peculiar protoconch resembles that of *H. minareta*, but its enormous size relative to the shell at once separates it from all the species here discussed. Its nearest relation is probably *minareta*, but apart from the size of the protoconch, it is smaller, with fewer whorls, and also differs in details of the sculpture. The specimen from Christmas I. agrees in every detail with the type, and the 2 specimens viewed side by side under the microscope cannot be told apart. This is interesting, for though on approximately the same latitude the 2 localities are about 1500 miles apart.

HOROLOGICA PINEA (Hedley)

Fig. 50

Joculator pinea Hedley, 1909, Proc. Linn. Soc. N.S.W. **34**: 440, pl. 40, fig. 55.

The specimen illustrated is from the type locality and was sorted from unclassified material collected by C. Hedley at 5-10 fm, Hope Is. It matches the type well but is not quite so inflated, and the purple colour is much faded. Hedley gives the colour as purple with cream bands. Its length is 2 mm compared with 2·35 mm for the type. Hedley's description, not his figure, gives about 19 tubercles to the whorl; this specimen and Hedley's figure show about 15. The protoconch unfortunately is unknown. More and better material is necessary before the full characters of this species can be elucidated.

HOROLOGICA PINEA NIGROPHYLA, subsp. nov.

Fig. 51

Two small specimens with no protoconchs and with slightly broken apertures were collected by J. Laseron alive from under coral blocks at Heron I. in the Capricorns. They conform in general characters to typical *H. pinea* from the Hope Is. more than 600 miles to the north, but are smaller (that figured is only 1·8 mm in length), are even more inflated, and are very deep brown and almost black instead of purple in colour. They are here proposed as a geographical race of *pinea*, but further material, particularly specimens of both forms showing the protoconchs, may well show that they are distinct species.

Genus POTENATOMUS, gen. nov.

Type species *Potenatomus caputumere*, sp. nov.

Like *Horologica* in form and sculpture, but minute, of few whorls, and with a large tumid protoconch of 1½ whorls.

POTENATOMUS CAPUTUMERE, sp. nov.

Fig. 52

Shell minute, ovate, tumid, yellow with a white, porcellanous protoconch. The protoconch is comparatively very large, swollen, of 1½ whorls, the nucleus large and infolded. Mature whorls about 4, but the sutures are not defined, and it is difficult to determine the limit of each whorl. The body whorl is, however, contracted at the base, which is not excavate. Sculpture in all of about 9 rows of large, rounded tubercles, about 16 to the whorl, the row on the periphery the largest, the tubercles on the basal keel not fully developed. The tubercles are not connected from row to row, but are set on low, broad keels, with deeper channels between. Aperture comparatively large, the outer margin thin and sinuous, the canal behind the columella, circular and nearly enclosed. Columella short and broad, anteriorly truncate, and lirate. Length 0·9 mm.

Locality.—Off North West Cape, W.A., 53 fm (sorted by J. Laseron from sand sample provided by C.S.I.R.O., Cronulla), holotype.

Remarks.—This curious little species gives a mere glimpse of what is undoubtedly a large fauna of small Mollusca on the continental shelf in the Dampierian Province. It is by far the smallest of all the species discussed in this paper, and its comparatively huge protoconch should make its future recognition easy.

POTENATOMUS SECUNDUS, sp. nov.

Fig. 53

Shell minute, ovate, contracted at the base, yellowish, with 4 bands of chocolate, designating the uppermost (?) row of tubercles, columella also chocolate. Protoconch comparatively very large and tumid, of 1½ whorls, smooth, white and porcellanous. Mature whorls about 5, but the sutures are not distinguishable. Sculpture of about 11 spiral keels in all, gradually increasing in size, with a thin keel developing between the others on the body whorl. The keels are broken into small rounded tubercles, about 16 to the whorl, which become less defined on the body whorl. The tubercles are connected transversely from row to row by distinct cords, which divide the channels into nearly square pits. The base has a prominent cord just above the columella. Aperture subpentagonal, the outer margin thin, expanded, and slightly sinuous, the canal behind the columella, circular and nearly enclosed. Columella broad and anteriorly truncate. Length 1·4 mm.

Locality.—Off Christmas I., Indian Ocean, 100 fm, holotype.

Remarks.—Compared with *P. caputumere* this species is larger, has a different colour pattern and sculpture, and the protoconch is relatively not so large. The holotype was sorted from a small parcel of shell sand from which Iredale has already described several unique genera of minute gasteropods. The significance of this fauna is not yet understood, nor is its relationship with that of the Dampierian Province; but another species, *Horologica macrocephala*, has already been described as common to both this locality and Darwin far to the east.

Genus NOTOSEILA Finlay

Notoseila Finlay, 1926, Trans. Proc. N.Z. Inst. **57**: 382. Cotton, 1951, Rec S. Aust. Mus. **9**(4): 390.

Type species *Cerithiopsis terebelloides* Hutton (Finlay 1926, p. 382).

Certain Australian species have previously been listed under *Seila* of Adams, but Cotton (1951, p. 390) substituted the New Zealand *Notoseila* for them. The type of *Seila*,* *Triforis dextraversa*, came from Japan, and from the description is closely akin to the eastern Australian species. The main character emphasized by Adams is the sculpture, which consists of plain spiral keels, transverse sculpture being confined to minute striae between the keels. The form is slender, with many, straight-sided whorls, the sutures indeterminable. Finlay in proposing *Notoseila* relied largely on the protoconch, which he describes as of 4 convex and smooth whorls, the nucleus mammilate. The number of whorls in the protoconch is here not of great use for generic separation. All the Australian species so far examined have a protoconch with a small nucleus followed by an inflated whorl to make the apex mammilate, but the number of whorls following varies from 0 to 3, the minimum in the Peronian species *nigrofusca*, the maximum in *crocea*. In the absence of Japanese material for comparison, it is impossible to say whether the separation of Australian species from *Seila* is justified, but as species live in the tropics as well as in southern Australian seas, there is no geographical barrier to their range, north or south.

NOTOSEILA IREDALEI, sp. nov.

Fig. 54

Shell elongate, conical, the spire very slightly convex, colour pure white. Protoconch of 2½ whorls, slightly bulbous, with no discernible varix. Sutures indistinguishable, but number of mature whorls about 10. The sculpture is distinctive, of sharp, spiral keels only, of 2 orders, each larger keel followed by 2 thin ones, but the earlier whorls with only 1 thin one. Base excavate. Aperture subquadrate, the outer margin thin and indented by the keels, the columella short, very broad, and rounded anteriorly. Length 5 mm.

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* *Ann. Mag. Nat. Hist.* (3) **7**: 131 (1861).

Locality.—Michaelmas Cay, in shell sand (T. Iredale), holotype.

Remarks.—The alternation of 1 broad and then 2 thin keels separates this from all other species yet described.

NOTOSEILA CAPRICORNIA, sp. nov.

Fig. 55

Shell elongate, conical, spire flat, colour pale yellow, protoconch white. Protoconch of 3 whorls, apex blunt, terminated by a varix. Sutures not discernible, but mature whorls about 9 or 10. Base excavate. Sculpture of spiral keels only; apparently 3 to the whorl, of which the upper and lower are broad, with a narrow keel between. The narrow keel is absent on the earlier whorls. A double keel is on the base of the body whorl. Aperture subquadrate, the outer margin indented by the keels, thin, the canal behind the columella, wide and shallow and slightly oblique. Columella wide and straight, rounded anteriorly. Length 5·2 mm.

Locality.—Masthead I. (C. Hedley), holotype.

Remarks.—The narrow keel between the broader keels should be a ready guide towards the future recognition of this species. Compared with *N. iredalei* it is also relatively broader, and the spire is very slightly convex. The protoconch is also different.

Genus PARASEILA Laseron

Paraseila Laseron, Aust. Zool. **11**(4): 367.

Type species *Paraseila heronensis* Laseron, 1951, p. 367.

Like *Notoseila* in sculpture, but with a short, bulbous, and convex spire, restricted at the base as in *Joculator*. The protoconch is short and inflated, with 1½-2 whorls. The Peronian species *Seila halligani* Hedley also comes here.

PARASEILA HERONENSIS Laseron

Fig. 56

Paraseila heronensis Laseron, 1951, Aust. Zool. **11**: 367, figs. 39, 39*a*.

The drawing is from a paratype from Heron I., its length 4·5 mm. There should be no difficulty in recognizing this species, its bulbous form and deep brown colour being distinctive. Apart from *Joculator* and *Horologica*, both of which genera have entirely different sculpture, there is so far no other species of the family so broad in relation to its length.

PARASEILA AMPULLA, sp. nov.

Fig. 57

Shell comparatively short and tumid, bottle-shaped, bright yellow in colour, protoconch white. Protoconch short and swollen, of 1½ whorls, the nucleus large and infolded, no varix, the sculpture beginning gradually. Sutures not distinguishable, the number of whorls uncertain but probably 7 or 8. The sculpture is of spiral keels only, subequal in size, with narrow summits, and of about the same width as the channels between. Base rounded with 2 thin keels. Aperture subquadrate, the outer margin thin and indented by the keels, columella short, broad, and tapering, a layer of callus adjoining the aperture. Canal broad and shallow, behind the columella. Length 3·4 mm.

Locality.—Masthead I. (C. Hedley), holotype.

Remarks.—The bulbous form, rounded base, and tumid protoconch bring this within *Paraseila* as here defined. It is much narrower than *P. heronensis* and has a different colour.

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The author is deeply indebted, as in all his previous papers, to the wholehearted and generous assistance given by Mr. Tom Iredale, late conchologist at the Australian Museum, Sydney. Acknowledgment is also made to the Director of the Australian Museum for placing the Museum collections at his disposal. He owes much also to his son John, who collected material from Darwin and from various localities on the Queensland coast, and helped in the rather tedious task of sorting this material into its various groups.

This research has been assisted by a grant from the Science and Industry Endowment Fund.

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ADDITIONAL MICROPLANKTON FROM AUSTRALIAN LATE MESOZOIC AND TERTIARY SEDIMENTS

By Isabel C. Cookson*

[*Manuscript received October* 21, 1955]

Summary

New Australian Late Mesozoic species of *Gymnodinium* and *Deflandrea* (Dinoflagellata) and *Odontochitina* and *Palaeotetradinium* (Incertae Sedis) have been described. A new species of *Wetzeliella* from a South Australian Eocene deposit has thrown light on the taxonomic position of the genus. *Hystrichokolpoma cinctum* Klumpp (Hystrichosphaeridae) has been recorded from Victorian Tertiary deposits.

I. Introduction

Since the appearance of a paper by Deflandre and Cookson (1955) on Australian fossil microplankton, several new or unrecorded types have been isolated from sediments not previously available. These sediments include the deposit in the Nelson Bore, Vic. (Deflandre and Cookson 1955, pp. 246, 295) at 6233 ft, and the grey shales intersected at 581 and 600 ft by a bore at Cootabarlow, near Lake Frome, S.A. Both the Nelson Bore and the Cootabarlow sediments are salt-water deposits of Cretaceous age and each contains a microflora of which the sporomorph *Mohriosporites australiensis* Cookson, 1953, is a component. Dicotyledonous pollen grains are not present in the Cootabarlow deposits.

A Tertiary marine coaly sample from Noarlunga, S.A., has yielded an interesting new species of the dinoflagellate *Wetzeliella*. This deposit contains a microflora which is very similar to the microflora C of Cookson (1954), characterized by the sporomorph *Proteacidites pachypolus* Cookson & Pike, 1954, present in some of the Eocene deposits in Victoria, South Australia, and Western Australia.

II. Description of Types

Class **DINOFLAGELLATA**

Family **GYMNODINIDAE**

Genus GYMNODINIUM Stein

Gymnodinium nelsonense sp. nov.

Plate 1, Figs. 8-11

Upper Cretaceous: Nelson Bore, Vic., at 6233 ft.

The cell is roughly fusiform with a delicate, finely and faintly granular membrane; usually it is more or less longitudinally folded and at approximately half its length transversely crumpled, so that the nature and even the existence of a transverse girdle is difficult to determine; a slight waist-like narrowing (Plate 1, Fig. 8) delimits a broad "epitheca" with a bluntly rounded apex from a somewhat longer "hypotheca", which gradually narrows towards a rounded or truncate antapex; frequently a small oval opening seems to be present at this end of the cell (Plate 1, Fig. 10).

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Dimensions (approximate on account of folding).—Holotype (Plate 1, Fig. 10): length 70 μ, width 38 μ. Paratypes shown in Plate 1, Figure 8, 120 × 39 μ, and Plate 1, Figure 11, 75 × 36 μ.

This organism is fairly numerous in the Nelson Bore sediment at 6233 ft. It is referred to *Gymnodinium* because of a general agreement with some of the living and fossil species. Of the latter, *G. nelsonense* seems most closely allied to *Gymnodinium digitus* Defl., a single individual of which was described from a ?Senonian flint of the Paris Basin (Deflandre 1934). Both have thin membranes, the granulations of which tend to be arranged longitudinally. *Gymnodinium paradoxum* Schilling (1913) is a living species with an ill-defined girdle.

Family **DEFLANDREIDAE**

Genus **DEFLANDREA** Eisenack

DEFLANDREA CRETACEA sp. nov.

Plate 1, Figs. 1-7

Upper Cretaceous: Nelson Bore, Vic., at 6233, 6065, and 5304 ft.

Cell always encysted. Theca broadly and bluntly fusiform to almost circular in outline, truncate or slightly concave posteriorly, either concave, rounded, or broadly tapered anteriorly; epitheca sometimes with a minute blunt median projection (Plate 1, Fig. 4); neither transverse girdle nor longitudinal furrow observed; in the region of the cyst one face is plane, the other convex.

The cyst, which is generally crumpled, is large in proportion to the size of the cell, and when fully expanded occupies the greater part of the theca (Plate 1, Fig. 3). A clearly marked, roughly polygonal aperture is present on the convex side of the epitheca.

The membrane of the theca is more or less coarsely granular, that of the cyst is smooth.

Dimensions.—Holotype (Plate 1, Fig. 1): theca 55 μ long and 52 μ broad. Range: length of theca 45-65 μ, breadth of theca 43-56 μ.

D. cretacea is of essentially the same type as *Deflandrea bakeri* Deflandre & Cookson, 1955 (Paleocene Pebble Point Formation, Vic.), and *D. bakeri* f. *pellucida* Defl. & Cookson (Nelson Bore, Vic., at 3874 ft), but differs from both in its length, which is only about half that of these forms, and in the absence of a well-marked anterior prominence. It is questionable whether these differences are sufficient to justify specific distinction. Wood (1954, p. 175) has noted that frequently amongst living dinoflagellates "a given size group is dominant in any one catch, but when the same species, e.g. *Gonioderma*, varies in size in a catch two distinct size-groups occur, representing, no doubt, different generations of the same species". Wood suggests that size as a differential character should be used with caution. However, in view of the considerable depth that separates the sediments containing *D. cretacea* and *D. bakeri* f. *pellucida*, and the impossibility of satisfactorily resolving such a question with fossil material, it has seemed desirable to specifically differentiate the older, simpler, and consistently smaller Cretaceous form from *D. bakeri* and its form *pellucida*.

The few examples isolated from the Nelson Bore at 5304 ft diverge somewhat from *D. cretacea* in its typical form; the membrane of the epitheca tends to be more coarsely granular and the cysts are thicker-walled. In the specimen shown in Plate 1, Figure 7, the membrane of the hypotheca is smooth.

Usually the cysts of *D. cretacea* contain small groups of variously placed spherical bodies similar to those reported by Eisenack (1954) as occurring in *Deflandrea phosphoritica* Eis. Eisenack made the suggestion that such bodies might be nuclei.

As far as the Australian examples are concerned, this view is improbable because of the severe treatment with Schultz's macerating mixture (nitric acid + potassium chlorate followed by 10 per cent. sodium hydroxide), to which the deposits containing *D. cretacea* were subjected. This mixture would almost certainly destroy any protoplasmic bodies that might have escaped decay during fossilization. It seems more likely that such bodies represent some kind of organic decomposition product.

D. cretacea is the first species of *Deflandrea* to be described from a Cretaceous deposit. The sediment in which it is most abundant is situated approximately 450 ft below the bed at 5782 ft in the Nelson Bore, which is believed to be Upper Cretaceous (Deflandre and Cookson 1955) because it contains *Odontochitina cribropoda* Defl. & Cookson, *Hystrichosphaeridium complex* (White) Defl., and *H. pulcherrimum* Defl. & Cookson. These forms have been found in the Upper Cretaceous Lower Greensand at Gingin, W.A., but not in any of the Australian Tertiary deposits so far examined.

Genus WETZELIELLA Eisenack

WETZELIELLA ARTICULATA (O. Wetzel) Eisenack

Plate 2, Fig. 1

Peridinium sp. ind. O. Wetzel, 1935, Jber. niedersächs. geol. Ver. **61**: pl 10, fig. 1.

Wetzeliella articulata Eisenack, 1938, Schr. phys.-ökon. Ges. Königsb. **70**: 183. Reissinger. 1950, Palaeontographica B **90**: 119, pl. 19, fig. 6. Klumpp, 1953, Palaeontographica A **103**: 393, pl. 19, figs. 1-3.

Hystrichosphaeridium articulatum Pastiels, 1948, Mém. Mus. Hist. Nat. Belg. **109**: 42, pl. 4, figs. 12-17.

Eocene: Carbonaceous mudstone at the base of the Dartmoor Formation, near Casterton, Vic.

Several specimens having the general characters of the European species *Wetzeliella articulata* have been recovered from the Dartmoor Formation in western Victoria. Each possesses a large central body, or cyst, and the cell membrane bears numerous simple or bifurcate processes. The example shown in Plate 2, Figure 6, which measures 64 μ × 53 μ without appendages, is more like the one illustrated by Klumpp (1953, Plate 19, Figs. 1 and 2) from an Upper Eocene deposit (Bore Wöhrden) in Holstein, Germany, than any of those from the Oligocene phosphorites of Samland, Prussia, figured by Eisenack (1954). In both the Bore Wöhrden and Dartmoor examples the angles of the cell, at which points the processes tend to be more prominent, are approximately equidistant from one another.

W. articulata is generally similar to *W. homomorpha* Defl. & Cookson, 1955, from the Princetown Member of the Dilwyn Clay of the Victorian Lower Tertiary succession, but as yet a cyst has not been observed in *W. homomorpha* from either the type locality or from the Nelson Bore, Vic., at 1553 ft, at which level it has recently been found. The appendages of *W. homomorpha* seem to be consistently smaller than those of *W. articulata.*

WETZELIELLA GLABRA sp. nov.

Plate 2, Figs. 1-5

Eocene: Carbonaceous clay from Noarlunga, south-east of Adelaide, S.A.

Cell encysted, flattened, quadrangular in outline with an entire margin, divided equally by a transverse girdle into a triangular epitheca with a short, bluntly pointed apical horn and a hypotheca with 2 short, unequal horns. The girdle is most clearly evident in the position of the lateral horns. The cell membrane is finely granular and usually completely smooth; in the holotype a few minute teeth-like outgrowths are present in the region of the horns, particularly the apical horn.

The cyst, which is separated from the cell membrane by a wide space, is ellipsoidal and flattened, and has a moderately thick, roughened wall with a granular sculpture (Plate 2, Fig. 4). An approximately quadrangular opening has been present in all the specimens, and the detached "lid" can sometimes be seen lying in the cell cavity.

Dimensions.—Holotype (Plate 2, Fig. 1): cell 137 μ long × 126 μ broad; cyst 82 μ long × 82 μ broad. Paratype (Plate 2, Fig. 5): cell 117 μ broad, cyst 75 μ long × 73 μ broad.

Since the genus *Wetzeliella* Eisenack was instituted for flattened rhomboidal organisms with, almost invariably, a strongly marked external ornamentation in the form of branched or unbranched spike-like appendages, the present reference of a flattened rhomboidal type with a smooth membrane to *Wetzeliella* may be open to criticism. In fact, it was for just such forms from Oligocene Septaria clays of northern Germany that Gocht (1955) proposed his new genus *Rhombodinium.*

In referring the Noarlunga specimens to *Wetzeliella* instead of to *Rhombodinium* I have been largely influenced by the existence of what appears to be an "intermediate" species, namely, *W. lineidentata* Defl. & Cookson, 1954, from Western Australia. In this species the ornament takes the form of short, blunt, rather widely spaced spines which appear to be the much reduced equivalents of the spike-like processes of the European species. From the occurrence of such a reduced type of appendage in an undoubted species of *Wetzeliella*, it seems reasonable to assume that the absence of ornament from the membrane of both *W. glabra* and *Rhombodinium draco* Gocht could have resulted from suppression within the limits of a single genus. This assumption is further supported by the occurrence of clearly defined spinules in the region of the apical horn of the holotype of *W. glabra.* It would appear, therefore, that a series of species of approximately similar form exists in which the chief variant is the type and extent of development of the external ornament.

The most interesting feature of *W. glabra* is its possession of an unmistakable transverse girdle. This characteristic dinoflagellate character has not been clearly indicated in the other species of *Wetzeliella*, nor in *Rhombodinium draco*. Thus, whether or not *W. glabra* be finally accepted as a valid species of *Wetzeliella*, it has settled existing doubts (Eisenack 1954) regarding the taxonomic position of similar morphological types, and has fully established their connexion with the Dinoflagellata, as originally suggested by Deflandre (1952) and accepted by Eisenack (1954).

Apart from the presence of a transverse girdle, *W. glabra* appears to be morphologically close to *R. draco*, especially to the example illustrated by Gocht (1955, Fig. 1*a*), but the two species are by no means identical. As far as can be judged from the illustrations, the shape of the lateral horns differs in the two forms, and the cysts are both differently shaped and thinner-walled in *R. draco* than in *W. glabra*. It seems clear, therefore, that whatever decision is reached regarding the generic position of these two forms, they are specifically distinct from one another.

Order HYSTRICHOSPHAERIDEA

Family HYSTRICHOSPHAERIDAE

Genus HYSTRICHOKOLPOMA Klumpp

HYSTRICHOKOLPOMA CINCTUM Klumpp

Plate 2, Figs. 7-9

Hystrichokolpoma cinctum Klumpp, 1953, Palaeontographica A **103**: 389, pl. 17, figs. 3-5.

Eocene: Carbonaceous deposit from Noarlunga, S.A.; Nelson Bore, Vic., at 992 ft.

?Oligocene: Nelson Bore, Vic., at 730 ft.

Shells which appear to be referable to the European species *Hystrichokolpoma cinctum* as defined by Klumpp (1953) and further exemplified by Eisenack (1954) have been recovered from the deposits listed above. The shells carry appendages of two sizes, some of the narrower ones being equatorially arranged (Plate 2, Fig. 8). The larger appendages are variable in shape; some are cylindrical and longer than broad, others are conical and approximately as broad as long. Both Klumpp and Eisenack have maintained that the larger appendages of *H. cinctum* are open distally. In the Australian examples a clearly defined opening with a finely serrated edge has occasionally been observed, but usually the appendages have been too much flattened and wrinkled to allow a decisive conclusion as to the constancy of this feature to be reached.

The examples of *H. cinctum* from the Nelson Bore at 730 ft are considerably smaller than the single specimen from the deposit in the Nelson Bore at 992 ft (Plate 2, Fig. 8), and the two examples obtained from the Noarlunga coaly deposit, and may represent a distinct type. However, Eisenack has noted a considerable size range in his collection of *H. cinctum* from Oligocene phosphorites of Samland, Prussia.

H. cinctum is readily distinguishable from *H. rigaudae* Defl. & Cookson, 1954, with which it occurs in the Nelson Bore deposits at 730 and 811 ft, by the absence from the larger appendages of the secondary processes, which are almost invariably present in those of *H. rigaudae*. The latter seems to be a sturdier form.

The extra-Australian stratigraphical distribution of *H. cinctum* as at present known is as follows:

Upper Eocene: Bore Wöhrden, Holstein, Germany (Klumpp 1953).

Lower Oligocene: Phosphorites, Samland, East Prussia (Eisenack 1954).

Oligocene: Innien, Holstein, Germany (Deflandre and Cookson 1955, p. 280).

INCERTAE SEDIS

Genus ODONTOCHITINA Deflandre

ODONTOCHITINA PORIFERA sp. nov.

Plate 1, Fig. 17

Upper Cretaceous: Nelson Bore, Vic., at 6233 ft.

The organism consists of a globular body with 2 stout appendages, and an operculum with a single broader anterior horn. The walls of the posterior appendages are perforated in the middle portions by small, rather regularly arranged holes, and are entire at the pointed apices and short proximal regions. The wall of the larger anterior horn is almost completely perforated by small 4-sided or oval openings, which are arranged in several longitudinal rows that extend from the base to a short distance behind the narrowed apex. Only 2 complete examples have been found, and in neither of these has the extreme tip of the anterior process been preserved.

Dimensions.—Holotype: overall length 208 μ, body 78 μ broad; anterior horn 78 μ long, 31 μ broad; posterior appendages 65 μ and 57 μ long, 16 μ broad. Second complete specimen: overall length 234 μ, body 81 μ broad; anterior horn *c.* 96 μ long, 39 μ broad; one of the posterior appendages 70 μ long, 29 μ broad.

O. porifera is apparently closely related to *O. cribropoda* Deflandre & Cookson, 1954, from the Nelson Bore, Vic., at 5782 ft and the Cretaceous Lower Greensand at Gingin, W.A. In both species the walls of the appendages are perforated, whereas in the genotype, *O. operculata* (O. Wetzel) Defl. from the European and Australian Cretaceous deposits, the walls of the appendages are entire throughout.

O. porifera is a more robust type than *O. cribropoda* and also differs in the position of the perforated areas of the appendages. In *O. cribropoda* the appendages are club-shaped and the perforations are restricted to the distal regions. In *O. porifera*, on the other hand, the apices are pointed and their walls entire.

O. porifera is not a common form; apart from the two entire specimens only a few fragments carrying one or two appendages of typical form have been recovered.

Genus PALAEOTETRADINIUM Deflandre

PALAEOTETRADINIUM HYALODERMUM sp. nov.

Plate 1, Figs. 12-16

Cretaceous: Onepah Station, near Tibooburra, N.S.W. (Deflandre and Cookson 1955, pp. 246, 294). Cootabarlow Bore near Lake Frome, S.A., core at 581 and 600 ft. Several samples from the West Australian Petroleum Company: Leederville Sandstone, W.A., samples from Attadale Bore, taken at 809, 839, and 999 ft; Grierson No. 3 bore, core 9, at 1390-1400 ft; Rough Range, well No. 8, core 1 from 1530 to 1548 ft, Upper Gerlie (? Turonian); Rough Range, well No. 8, core 8 at 3863-3881 ft, Muderong (Albian-Cenomanian).

Cell small, tetrahedral, prolonged at each angle into a thin, cylindrical process* that tapers to a sharp solid point. Cell wall firm, hyaline, and smooth.

Dimensions.—Holotype (Plate 1, Fig. 12): diameter of body *c.* 21 μ, appendages 20-26 μ long. Another example (Plate 1, Fig. 14): diameter of body *c.* 18 μ, appendages 26-31 μ long.

It is doubtful whether these specimens should be referred to *Palaeotetradinium*, an inadequately known genus from Upper Cretaceous flints of the Paris Basin (Deflandre 1936), in preference to the equally obscure genus *Tetrabrachiophora* Eisenack (1954) from Oligocene phosphorites of Samland, Prussia. However, since the Australian organism approximates more closely in size to *Palaeotetradinium silicorum* Defl. (genotype) than to the very much larger *T. natans* Eis., it is temporarily included in *Palaeotetradinium* until more information about all three types becomes available.

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* An example from Grierson No. 3 bore (Plate 1, Fig. 16) has two processes at each angle.

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Explanation of Plates 1 and 2

All the photographs are from untouched negatives.

Plate 1

Fig. 1.—*Deflandrea cretacea* sp. nov. Holotype. Nelson Bore, Vic., at 6233 ft. × *c.* 585. P16705.*

Figs. 2-5.—*Deflandrea cretacea.* Paratypes showing variations in size and shape. Nelson Bore at 6233 ft. × 550. P16706-16709.

Figs. 6, 7.—*Deflandrea cretacea.* Paratypes. Nelson Bore at 5304 ft. × 550. P16710, 16711.

Figs. 8, 9, 11.—*Gymnodinium nelsonense* sp. nov. Paratypes. Nelson Bore, Vic., at 6233 ft. × *c.* 585 (Fig. 8) and *c.* 600 (Figs. 9, 11). P16707, 16713, 16705.

Fig. 10.—*Gymnodinium nelsonense.* Holotype. Nelson Bore at 6233 ft. × *c.* 600. P16715.

Fig. 12.—*Palaeotetradinium hyalodermum* sp. nov. Holotype. Cootabarlow Bore, core at 581 ft. × *c.* 400. P16716.

Fig. 13.—*Palaeotetradinium hyalodermum.* One of the appendages of the holotype. × *c.* 800.

Fig. 14.—*Palaeotetradinium hyalodermum.* Paratype. Cootabarlow Bore, sludge from between 600 and 610 ft. × *c.* 400. P16717.

Fig. 15.—*Palaeotetradinium hyalodermum.* Paratype. Cootabarlow Bore, core at 581 ft. × *c.* 410. P16718.

Fig. 16.—*Palaeotetradinium hyalodermum.* Paratype. Grierson No. 3 bore at 1390-1400 ft. × 550. P16719.

Fig. 17.—*Odontochitina porifera* sp. nov. Holotype. Nelson Bore, Vic., 6233 ft. × 380. P16720.

Plate 2

Fig. 1.—*Wetzeliella glabra* sp. nov. Holotype. Noarlunga, S.A. × *c.* 550. P16721.

Fig. 2.—*Wetzeliella glabra.* Extreme tip of apical horn holotype showing "teeth". × *c.* 800.

Fig. 3.—*Wetzeliella glabra.* Paratype. A free cyst showing the position of the preformed opening at the anterior end. Noarlunga, S.A. × *c.* 550. P16722.

Fig. 4.—*Wetzeliella glabra.* Portion of the wall of the previous specimen to show the type of sculpture. × *c.* 800.

Fig. 5.—*Wetzeliella glabra.* Paratype. Noarlunga, S.A. × 280. P16723.

Fig. 6.—*Wetzeliella articulata* Eisenack. Dartmoor Formation, Vic. × *c.* 540. P16724.

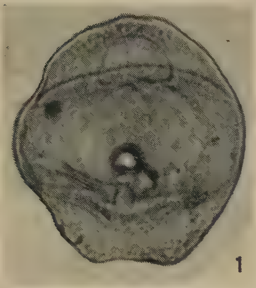
Fig. 7.—*Hystrichokolpoma cinctum* Klumpp. Nelson Bore, Vic., at 730 ft. × 550. P16725.

Fig. 8.—*Hystrichokolpoma cinctum.* Nelson Bore, Vic., at 992 ft. × 550. P16712.

Fig. 9.—*Hystrichokolpoma cinctum.* Noarlunga, S.A. × 550. P16711.

* References so given are the registered numbers in the palaeontological collection of the National Museum of Victoria.

MICROPLANKTON FROM AUSTRALIAN SEDIMENTS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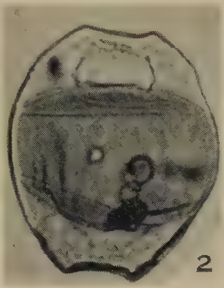
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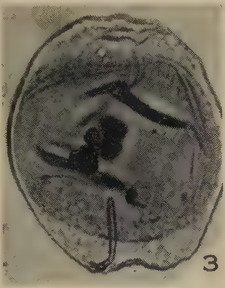
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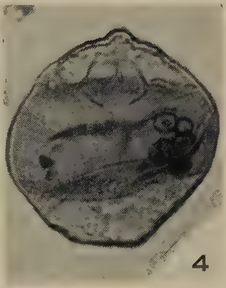
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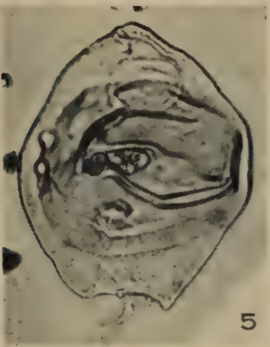
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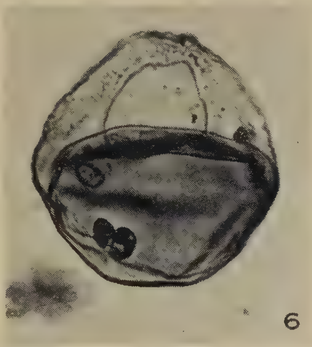
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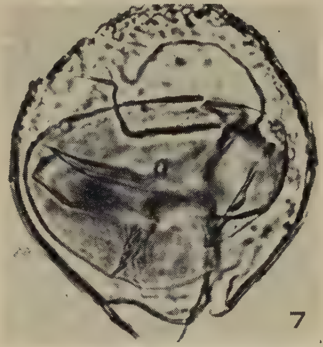
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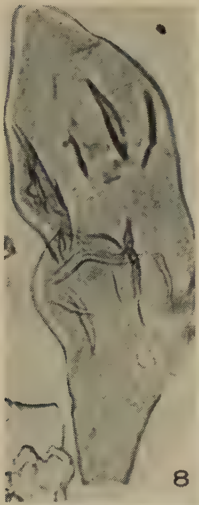
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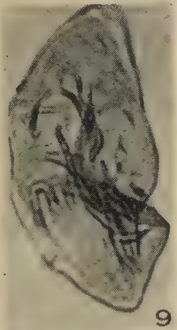
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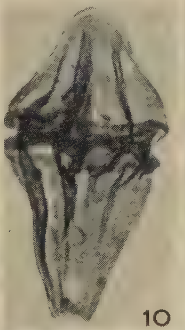
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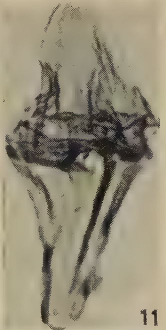
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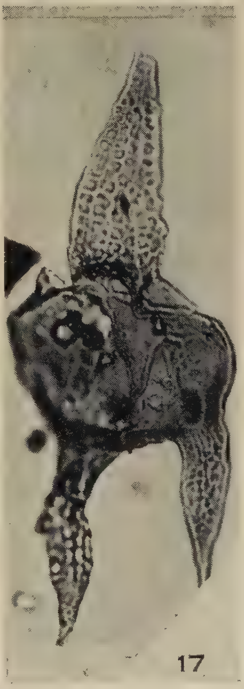
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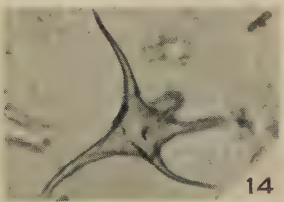
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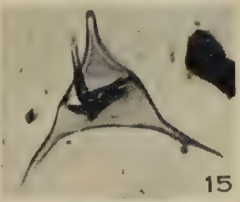
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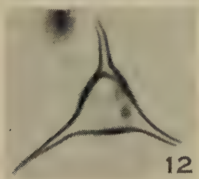
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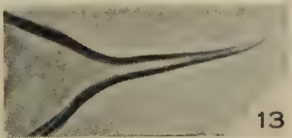
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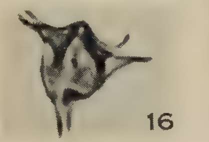
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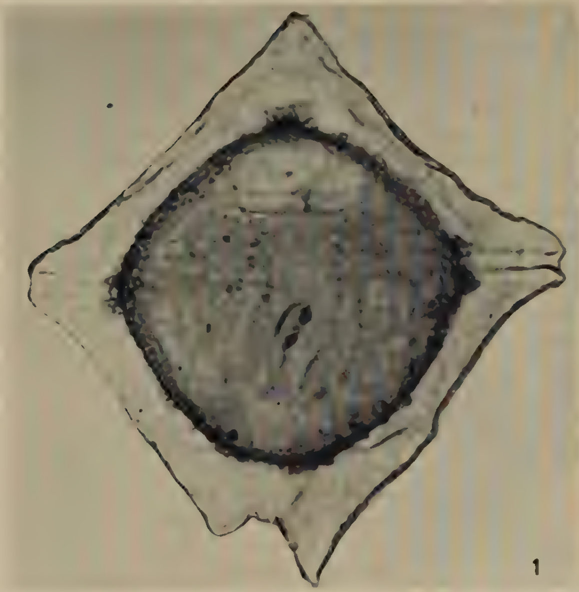
MICROPLANKTON FROM AUSTRALIAN SEDIMENTS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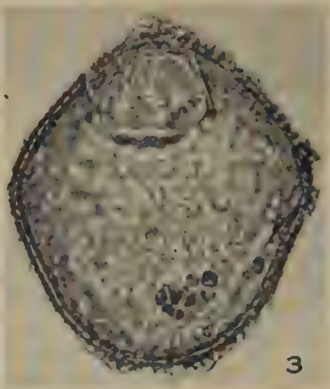
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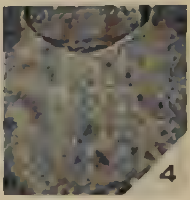
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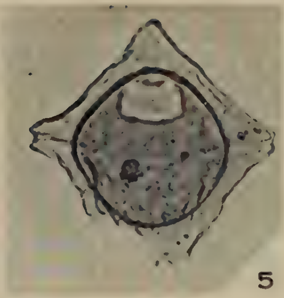
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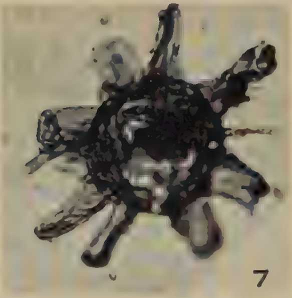
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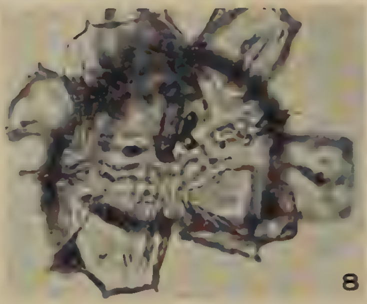
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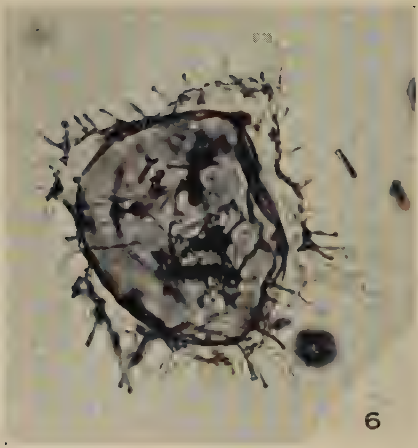
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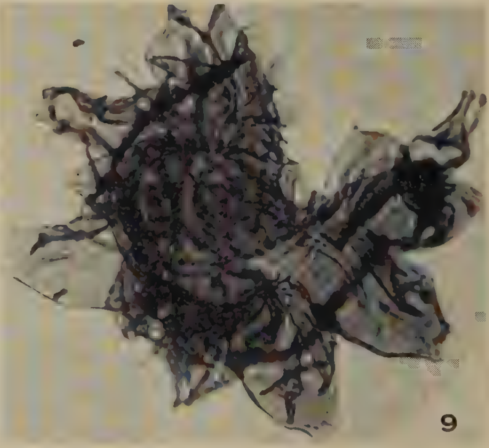
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LIST OF SPECIES

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CORRIGENDA

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The following species, given as new in this paper, were actually named and figured in an earlier publication (Deflandre and Cookson, *C.R. Acad. Sci., Paris* **239**: 1235 (1954)), and should therefore be designated "Deflandre & Cookson, 1954", not "sp. nov.":

> *Hystrichodinium oligacanthum, Wetzeliella lineidentata, Deflandrea heterophlycta, Palaeohystrichophora minuta, Eisenackia* (gen. nov.) *crassitabulata, Hystrichosphaera crassipellis, Hystrichosphaeridium pulcherrimum, H. choanophorum, H. striatoconus, Hystrichokolpoma rigaudae, Cymatiosphaera imitata,* and *Odontochitina cribropoda.*

Page 251, line 22: *For* Plate 3, Fig. 2, *read* Plate 4, Fig. 1.

Page 254, line 15: *For* Figs. 17 and 18 *read* Fig. 19.

Page 259, line 7 from bottom: *For* medium *read* median.

Page 263, line 5 from bottom: *For* Plate 5, Fig. 6, *read* Plate 5, Fig. 8.

Page 287, explanation of figures, line 4: *For clathroderma read clathrodermum.*

Page 311, explanation of Plate 7, Fig. 6: *For clathroderma read clathrodermum.*

VOLUME 6, NUMBER 3

Page 448, caption to side scale of Figure 3: *For* PHOSPHATE *read* PHOSPHORUS.

VOLUME 7, NUMBER 1

Page 52, Figure 3, west coast, between 17 and 18, opposite arrow: *Insert* 15.

STUDIES IN AUSTRALIAN ESTUARINE HYDROLOGY

II. THE SWAN RIVER

By R. S. Spencer*

[*Manuscript received August 2, 1955*]

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Summary

The physiography of the Swan River is described, with particular reference to the drowned valley basin which is connected to the sea across a shallow sill. The climatological features of the region are discussed, together with the tidal characteristics of the basin. Drought conditions prevail during the summer, effective rainfall being confined to the winter months. Density stratification in the basin is intense and prolonged, because of the weakly developed tidal mixing.

Changes in the mean water level of the basin are correlated with variations in barometric pressure; the amplitude of these changes sometimes exceeds that of the lunar tides. This fact has a significant bearing on hydrological conditions within the basin.

The distribution and the seasonal cycles of temperature, chlorinity, and oxygen saturation are compared with those of a tidal-dominated estuary situated at the same latitude in eastern Australia. Most of the differences in these cycles can be attributed to the tidal regimes of the two systems.

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* Division of Fisheries and Oceanography, C.S.I.R.O., Cronulla, N.S.W.

Nutrient cycles within the Swan River basin are discussed with particular reference to the recovery period following the development of stratification. In the later stages of the investigation this period was studied intensively, and from the information obtained several theories are advanced to explain the circulatory features of the basin region.

An attempt is made to classify the Swan River estuary.

I. Introduction

Rochford (1951), in a general survey of estuarine types in Australia, has referred to those of south-western Australia, where the two dominant factors are: (1) a poorly developed tidal oscillation; (2) a characteristic rainfall regime which allows freshwater discharge to occur only during a limited period of the year. This author clearly demonstrates the essential differences between these systems and those of south-eastern Australia, which are subjected to a far greater tidal influence and a different rainfall regime.

A reiteration of Rochford's introductory remarks would not be out of place at this stage. Many estuarine studies have in the past been either ecological (Alexander, Southgate, and Bassindale 1935; Milne 1937; Pritchard 1952*a*) or dynamical (Ketchum 1951; Pritchard 1952*b*; Stommel and Farmer 1952; Preddy 1954). Ström (1936) has studied a number of Norwegian fjords, most of which are of a considerable depth; his observations were confined to the northern summer period, when melting snow contributes large quantities of warm fresh water to the surface layers, thus inducing a considerable thermocline. Tully (1949) studied the stratification of Alberni Inlet as part of a programme to enable predictions to be made of the fate of pulp mill effluent within the system; in other words, his investigations were designed to elucidate a particular problem of pollution.

The investigations carried out on the Swan River have been on a long-term basis, their primary objective being the collection of sufficient data to establish seasonal fluctuations in certain hydrological properties. This work led to an intensification of sampling in the region below station 7 in 1953 and 1954, to study the recovery of the system from winter flooding. Because of a complete lack of previous data the work has in its early stages been more general than many other similar studies, with a more recent emphasis on the processes occurring in the basin region; in the course of realizing the primary objective many problems have been encountered which still require elucidation.

A concept of zonal classification of estuaries was developed by Rochford (1951), mainly as a result of investigations carried out on selected systems in eastern Australia. In view of the poorly developed tidal influences existing in the estuaries of south-western Australia it was decided to initiate the investigations which are discussed in this paper, with a view to attempting some zonal classification of the Swan River.

The problem is greatly complicated by the nature of freshwater discharge into this system. Not only is the seasonal variability of the discharge most pronounced, but it actually ceases during the summer months, so that during this period the horizontal distribution of chlorinity is controlled almost entirely by tidal influences. In other words, the zonal characteristics of the system are dependent on two components, one of which is reasonably constant (tide), the other extremely variable (rate of freshwater discharge). In the lower range of the variable component the system becomes marine-dominated, whereas in the upper range the surface waters at least become freshwater-dominated. Neither of these phases could be described as transitory, since each persists continuously for weeks and sometimes months. During the transition period between the two phases it is possible for a gradient zone to develop within the system. This process is more pronounced when the chlorinity of the surface waters is rising during spring; the development of a surface layer of fresh water in winter is often so rapid that no such gradient is observed for a significant period of time.

Stommel and Farmer (1952) have divided estuaries into four types according to the degree of vertical mixing: (1) non-stratified systems, in which vertical mixing is intense; (2) highly stratified systems, in which mixing is weakly defined; (3) salt-wedge systems, in which a tongue of salt water forces its way upstream; (4) slightly stratified systems, which maintain reasonable efficiency of vertical mixing. Because of its peculiar rainfall regime, the Swan River conforms to no single type described by these authors, whose classification differentiates on the basis of efficiency of vertical mixing and not necessarily on that of the intensity of freshwater contribution. As the Swan River basin is dominated so completely by this latter factor, it can be placed in each of the four categories at different stages of the seasonal cycle. Irrespective of whether the efficiency of vertical mixing is greater in the summer than in the winter, the fact remains that stratification is absent in summer and intense in winter; also that a sea-water wedge can be observed in the early stages of the system's reaction to flooding, and that subsequently stratification is gradually reduced to a stage where it can be described as slight.

Several authors have referred to the principle of estuarine circulation which prevents a system from becoming completely fresh. During the dry summer period the Swan River provides an excellent example of this principle in reverse; marine water entering the system cannot mix with fresh water, simply because the latter is no longer being contributed from the headwaters. Therefore, the system becomes completely marine-dominated as far as station 7, the hydrological properties in this region being practically identical with those of the adjacent coastal waters. This condition persists for several months during the autumn, until the discharge of fresh water commences again.

II. METHODS

(a) *Sampling Procedure*

In the early stages of the investigations the sampling procedure consisted of monthly collections at surface and bottom, from stations 1 to 8; surface samples only were collected between stations 9 and 13. This programme began in 1947 when a permanent hydrological laboratory was set up in the University of Western Australia. Sampling had actually commenced in 1944, but the absence of such a laboratory had made it difficult to maintain on a regular basis. Monthly sampling at all stations continued until the end of 1952, after which it was decided to concentrate on the region between stations 3 and 7, the Swan River basin. As soon as the winter rains commenced the stations within this region were sampled at 2-m intervals from surface to bottom. Occasionally samples were also collected at odd metre levels when temperature observations indicated a mixing boundary. This sampling was carried out at weekly intervals during the early stages of run-off, and continued until summer conditions were established. In this way the distribution of hydrological properties was studied vertically as well as horizontally, and several interesting aspects of circulation became apparent.

(b) *Field and Laboratory Techniques*

All water samples were collected with Nansen reversing bottles, and temperatures were recorded with reversing thermometers up to July 1953. Subsequently, the use of a portable thermistor unit enabled a more rapid and efficient survey of temperature distribution to be carried out.

Measurements of current velocity were made using the drag technique described by Pritchard and Burt (1951). Because of the low velocities the instrument had to be slightly modified, but the principle of its operation remained unchanged. Thin aluminium sheeting was used instead of wood, so that the possibility of water absorption was eliminated. Its dimensions were 12 by 18 in., giving a weight in water of about 20 oz. The weight which was usually added to this drag increased the weight in water to about $2\frac{1}{2}$ lb. A light cord, marked at metre intervals, was used to suspend the instrument in the water. Because of its light weight it could not be run through a metre wheel and had to be operated manually.

Several obstacles were encountered in the use of this technique on the Swan River. It was found to be successful only under ideal weather conditions; winds or currents which caused the anchored vessel to yaw considerably upset the efficiency of the instrument. The obvious solution, fore and aft mooring of the observation vessel, is often time-consuming and not always practicable.

The determination of transport volumes through a cross section of the system has so far been impossible. The tidal characteristics would necessitate a 24-hr series of observations at several stations across the section and the performance of this task during the hours of darkness has been impracticable.

The drag technique has therefore been employed in conjunction with surveys at fixed stations within the basin. Here it has been invaluable in the rapid determination of the direction and comparative speed of flow of the subsurface layers.

Two continuous tide recorders were installed at stations 3 and 6 during 1954; these machines were manufactured in the workshops of the Division of Fisheries and Oceanography, C.S.I.R.O., at Cronulla. The clocks have either 2- or 8-day settings, the latter being used as a routine. The charts are changed at weekly intervals.

The analytical techniques employed in the laboratory have already been described in some detail by Rochford (1951), and are referred to only briefly in this section.

(i) *Chlorinity.*—Chlorinity was determined by the standard Knudsen method on a 10 ml aliquot.

A portable chain pycnometer, developed by Rochford, Jitts, and Proctor (1955), was used on several occasions in the latter stages of the investigation, when a large number of chlorinity determinations had to be carried out either in the laboratory or the field.

(ii) *Dissolved Oxygen.*—Oxygen values, expressed as millilitres per litre at 20°C, were determined by the standard Winkler method, using sulphuric acid for the final acidification. From 1947 onwards the delay in the laboratory titration of the iodine solution never exceeded 1 week. Oxygen saturation figures are expressed as percentages of the theoretical values determined by Fox (1907).

(iii) *Hydrogen Ion Concentration.*—A Cambridge electrometer was used to determine pH, all values of which were corrected according to Buch (1937), and recorded as *in situ* values at atmospheric pressure.

(iv) *Inorganic Phosphate Phosphorus.*—This was determined by the method of Deniges (1920) as modified by Atkins (1923). The colorimeter described by Rochford (1951) was used up to 1948; thereafter a Spekker photoelectric absorptiometer was used with 4-cm cells and Ilford 608 red filters. When using the latter instrument a turbidity correction was applied to all samples by measuring the absorption after the addition of the molybdate reagent. After the addition of 0·1 ml of 1 per cent. stannous chloride the absorption was determined once again; the difference between the two readings was then used to obtain the concentration of inorganic phosphate phosphorus. Values were recorded as micrograms of phosphorus per litre, and no salt error corrections were applied.

(v) *Organic Phosphorus.*—The difference between total phosphorus, according to the method of Robinson (1941), and inorganic phosphate phosphorus, is expressed as organic phosphorus. In the determination of total phosphorus, 100-ml aliquots containing 0·2 ml 72 per cent. perchloric acid were evaporated to fuming point on an electric sand-tray. During the winter period the surface discharge waters are generally rather turbid, and in the digestion of such samples a watch-glass was placed on the flask once the fuming stage was reached. The acid condensed on the under-surface of the watch-glass and dropped back into the flask, thus making the digestion more effective.

Because of the lack of a suitable centrifuge it was not possible to separate the organic phosphorus into particulate and soluble fractions, as has been done in the Cronulla laboratories.

(vi) *Nitrate Nitrogen.*—The method used for the determination of nitrate has been described by Rochford (1947), the reagent being prepared by the reduction of strychnine by nascent hydrogen. A Klett visual colorimeter was used up to 1948, after which a Spekker absorptiometer was made available; 1-cm cells and Ilford 601 violet filters were used to determine absorption. No salt corrections were applied to the data, which were recorded as micrograms of nitrate nitrogen per litre.

(c) *Presentation of Data*

The hydrological data from which this paper has been prepared are contained in the Oceanographical Station Lists of the Division of Fisheries and Oceanography, C.S.I.R.O. (Spencer 1952; Rochford 1953; Rochford and Spencer 1953, 1955, 1956). All data obtained up to the end of 1950 appear in volume 8, 1951 data in volume 12, 1952 data in volume 15, 1953 data in volume 21, and 1954 data in volume 26.

Table 1

NUMBER OF COMPLETE SWAN RIVER SURVEYS IN EACH QUARTER FOR THE PERIODS 1944-1952 AND 1947-1952

Period	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Total
1944–1952	18	17	22	14	71
1947–1952	13	15	16	11	55

Maximum, mean, and minimum values of temperature, chlorinity, and oxygen saturation were calculated for all stations for the period 1944-1952. Because of the lack of permanent laboratory facilities prior to 1947 the storage factor for nutrient determinations was too uncertain, and therefore only data collected in the period 1947-1952 were used for the calculation of maximum, mean, and minimum values of phosphate phosphorus and nitrate nitrogen.

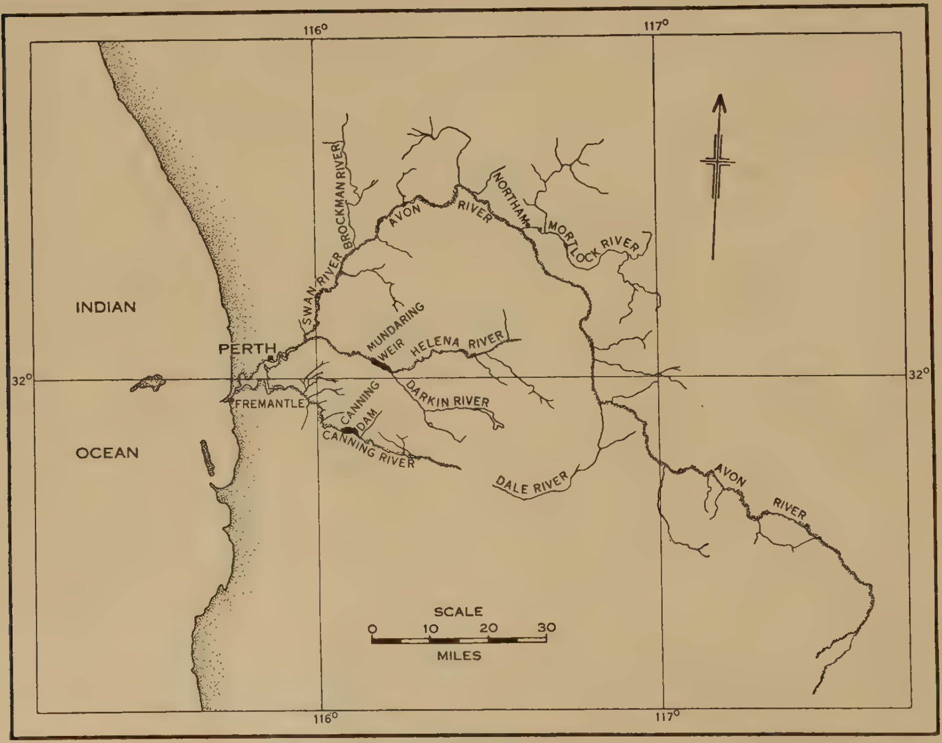
116°
117°
INDIAN
OCEAN
PERTH
FREMANTLE
32°
32°
SWAN RIVER
BROCKMAN RIVER
AVON RIVER
NORTHAM
MORTLOCK RIVER
MUNDARING WEIR
HELENA RIVER
CANNING DAM
CANNING RIVER
DARKIN RIVER
DALE RIVER
AVON RIVER
SCALE
0 10 20 30
MILES
116°
117°

Fig. 1.—Swan-Avon river system.

Table 1 shows the frequency of sampling during the two periods 1944-1952 and 1947-1952. Half the total number of complete surveys were made in each half of the year; as these periods correspond roughly to the dry and wet seasons, it is reasonable to assume that the data give an accurate picture of the annual range of properties. No use has been made of 1953 and 1954 data, as the sampling frequency was increased considerably in the second half of each year.

The figures in this paper illustrate several types of profiles. In the vertical depth profiles there is usually more than one curve in each figure, to illustrate either the relative distribution of several hydrological properties on the same date (e.g. Fig. 8), or the chronological changes occurring in the distribution of one or more properties (e.g. Fig. 22).

TABLE 2

SWAN RIVER STATION LIST

Station Number	Location	Distance from Mouth (miles)	Channel Depth (metres)
1	Mouth of Fremantle Harbour	0	10
2	Off Fremantle Traffic Bridge	2·4	5
3	Off Billygoat Farm	4·4	9
3*a*	Blackwall Reach	5·4	18
4	Off Point Walter	6·4	20
4*a*	Off Point Resolution	7·4	14
4*b*	Off Armstrong Spit	8·4	13
5	Off Applecross	9·6	12
5*a*	Canning Bridge	10·5	5
6	Off Crawley Bay	11·0	6
7	The Narrows	12·5	3
8	The Causeway	14·5	3
9	Maylands Jetty	17·0	—
9*a*	Smith's Bay	19·5	—
10	Ascot Bridge	21·8	—
11	McDonald's Dairy	23·8	—
12	Barker's Bridge	25·6	—
13	Middle Swan Bridge	30·6	—

Other types of profiles include the longitudinal profile of the Swan River basin (Fig. 36), and 24-hr profiles derived from observations at a fixed point over a period of time (Fig. 32). In the preparation of current velocity profiles (Fig. 34) further differentiation is necessary between ebb and flood isolines, and a zero line has also been entered on this type of profile.

III. PHYSIOGRAPHY

Jutson (1934) has described the Swan-Avon river system (Fig. 1), which rises on the plateau east of the Darling Scarp and is fed by numerous small streams and swamps; during the summer many of these are either completely dry or make no significant contribution to the Avon River. There is a gauging station at Northam, about 60 miles by road from Perth. Several small streams feed the Swan River downstream from this point during its descent of the Darling Scarp. Thence it flows as a narrow winding river through the sandy coastal plain, and enters a drowned valley where maximum depths of 20 m are encountered; this region is referred to hereafter as the Swan River basin. It is separated from the mouth (Fremantle

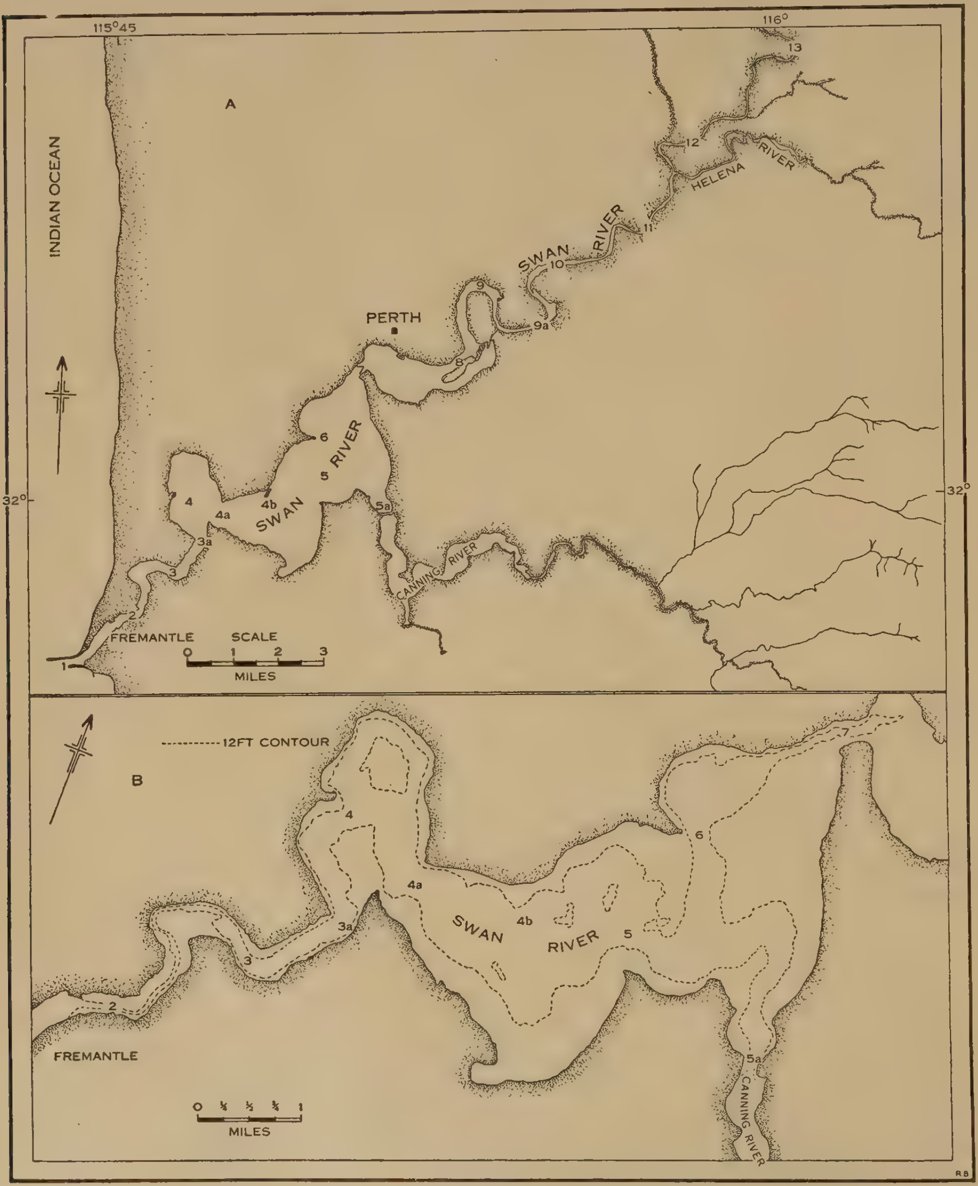
115°45
116°
A
INDIAN OCEAN
13
12
HELENA
RIVER
SWAN
RIVER
11
10
9
9a
PERTH
8
6
RIVER
5
SWAN
4b
4
4a
3a
5a
CANNING
RIVER
3
2
FREMANTLE
1
32°
32°
SCALE
0 1 2 3
MILES
B
12FT CONTOUR
7
4
6
4a
3a
SWAN
4b
RIVER
5
3
2
FREMANTLE
5a
CANNING RIVER
0 ¼ ½ ¾ 1
MILES
RB

Fig. 2.—*A*, Swan River station map; *B*, Swan River basin showing 12 ft contour line.

Harbour) by a narrow sill, with a channel depth of about 5 m, which extends from station 2 to within half a mile of station 3.

Table 2 gives the location, distance from the mouth, and channel depth of all stations; Figure 2*A* shows the distribution of those which were occupied at monthly intervals up to the end of 1952; the basin stations are shown in a more detailed map (Fig. 2*B*). Stations 3*a*, 4*a*, and 4*b* are additional basin stations which were included only in the intensive winter-spring sampling programme in 1953 and 1954.

The area of the basin is approximately 10 sq. miles, and a large proportion, particularly at the upper end, consists of shallow sandy banks, in depths less than 12 ft or 4 m. The average depth has been estimated at about 13 ft and the volume of water at about 20,000 million gal. Maximum depths are encountered between stations 3 and 4 (15-20 m); above this point the channel depth is steadily reduced to 3 m at station 7.

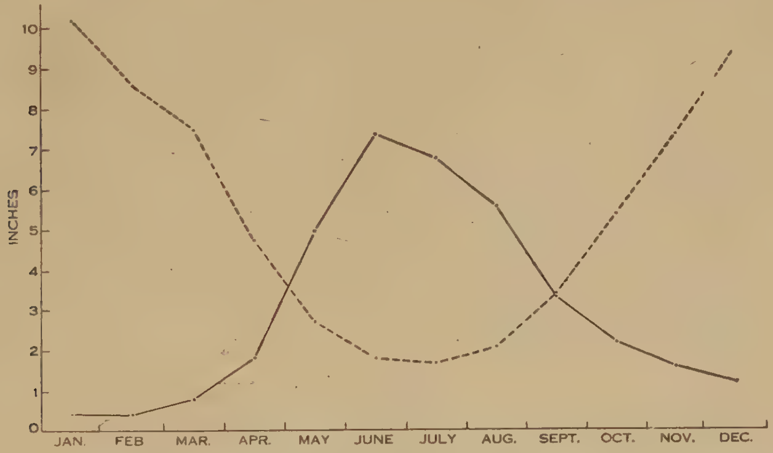

Fig. 3.—Monthly rainfall and evaporation at Perth Weather Bureau (period 80 years). —•— Rainfall; ---•--- evaporation.

Two tributaries enter the Swan River below station 13: the Canning River, which enters between stations 5 and 6, and the Helena River, which enters between stations 11 and 12. Both of these systems are dammed, the Canning for the water supply for the city of Perth and the Helena at Mundaring Weir, the source of the famous pipeline to the Kalgoorlie gold-fields 400 miles to the east.

IV. Climatological Features

(*a*) *Rainfall*

Figure 3 shows the seasonal cycle of rainfall and evaporation recorded at the Weather Bureau, Perth. It is obvious that the effective rainfall is confined to the winter months, and that during the long dry summer there can be no significant contribution of fresh water to the system. The onset of winter rains is associated with the appearance offshore of cyclonic depressions, which move in a south-easterly direction, generally passing to the west of Cape Leeuwin into the Great Australian

Bight. During spring the rainfall is produced by a series of cold fronts which move in from the sea in a somewhat irregular fashion.

(*b*) *Wind*

Table 3 shows the prevailing wind direction at certain times of the day for each month of the year. Summer conditions are characterized by the development of a land breeze, which blows during the night and early morning and is replaced later in the day by a south-westerly wind, usually of greater velocity.

TABLE 3
ANNUAL PREVAILING WIND DIRECTION AT PERTH
Period, 14 years

Month	Time of Day (hr)			
	0000	0600	1200	1800
January	S.	ESE.	S.	SSW.
February	SSE.	ESE.	SSE.	SSW.
March	SSE.	ESE.	SSE.	SSW.
April	SE.	E.	SE.	SSW.
May	E.	NE.	NNE.	SW.
June	NE.	NNE.	N.	WSW.
July	NE.	NNE.	NNE.	WSW.
August	SE.	NE.	NW.	SW.
September	S.	ENE.	SW.	SW.
October	S.	ESE.	SW.	SW.
November	S.	SE.	SSW.	SSW.
December	S.	SE.	SSW.	SSW.

Cloud formation during summer is slight, and humid conditions are the exception rather than the rule. Occasionally the sea breeze does not appear for several days, during which time air temperatures often exceed 100 °F under the influence of the warm dry land breeze. However, the persistence of south-westerly winds over considerable periods during the summer months must be stressed, in view of its possible effect on circulation within the basin during this period (Section VIII).

Although the data given in Table 3 show that the south-westerly component is present during the autumn months, it is important to observe that north-easterly land breezes appear during this period. Their velocity is usually low, giving rise to comparatively calm conditions; however, any intensification of this component heralds the development of the cyclonic depressions which bring the first winter rains from the north-west. As these depressions move further into the Great Australian Bight the wind shift occurs in an anti-clockwise direction, until the north-easterly component develops once again. Reference has already been made to the existence of cold fronts during the spring months, when rainfall rapidly decreases.

The region is occasionally influenced also by the development of stable high-pressure systems which induce persistent land breezes. These conditions have an important effect on the water level in the basin (Section V), and it is shown later that the resultant effect on hydrological properties is also very important (Section VIII).

V. TIDAL CHARACTERISTICS

The seasonal changes in weather conditions were discussed in some detail in the previous section because they have an important bearing on the tidal characteristics of the Swan River. Bennett (1939, 1940) has examined the factors responsible for the variations in mean sea-level and tidal range observed in the system, particularly in Fremantle Harbour, where tidal recording was commenced over 50 years ago.

The tidal oscillations are predominantly diurnal, but under certain lunar conditions a period of semi-diurnal tides is observed, the amplitude being greatly reduced. The mean sea-level is controlled by two factors: (i) a solar tidal wave, which is responsible for the annual variations in mean sea-level; (ii) changes in barometric pressure, which cause an inverse short-term variation in water level.

The hydrological significance of these short-term changes in water level are discussed in Section VIII. They are a reflection of similar changes in mean sea-level which occur in the shallow coastal waters of this region. When this outside level falls, a pressure head is developed within the estuary, so that there is a discharge of water from the latter; and notwithstanding the maintenance of tidal oscillations the mean water level of the basin falls until it reaches equilibrium with that of the onshore waters. When the outside level rises, the pressure gradient is reversed, so that sea-water moves into the basin and the level of the latter rises once again.

Maximum tidal velocities are encountered in the sill region, between stations 2 and 3, an important fact which has a considerable bearing on the circulatory processes occurring in the lower basin under stratified conditions. Within the basin proper, the velocity of tidal currents decreases rapidly, and the movement of water at the upper end is exceedingly sluggish, except at the height of winter run-off, when the establishment of a pressure head at the freshwater end of the system creates appreciable velocities in a seaward direction through the surface waters of the basin.

During the course of 24-hr surveys carried out at various Swan River stations as part of the present investigations, measurements of the rise and fall of water level disclosed a diurnal oscillation of about 1 ft within the basin. The installation of continuous tide recorders in the vicinity of stations 3 and 6 enabled these oscillations to be examined in greater detail; it soon became evident that a close relationship existed between mean water level and barometric pressure. Because of this relationship the variations in mean water level which are observed over a period of several days may, under suitable weather conditions, be significantly greater than any of the individual diurnal tidal ranges. This is one of the most outstanding differences between the tidal behaviour of eastern and south-western Australian estuaries; in the former the existence of semi-diurnal lunar tides, with a maximum amplitude of about 6 ft, completely masks any variations in water level which may be caused by local barometric conditions.

Figure 4 shows three tidal records made under different conditions of barometric pressure. In each case the variations in barometric pressure observed at the Perth Weather Bureau are plotted on the same time scale and wind arrows are also shown.

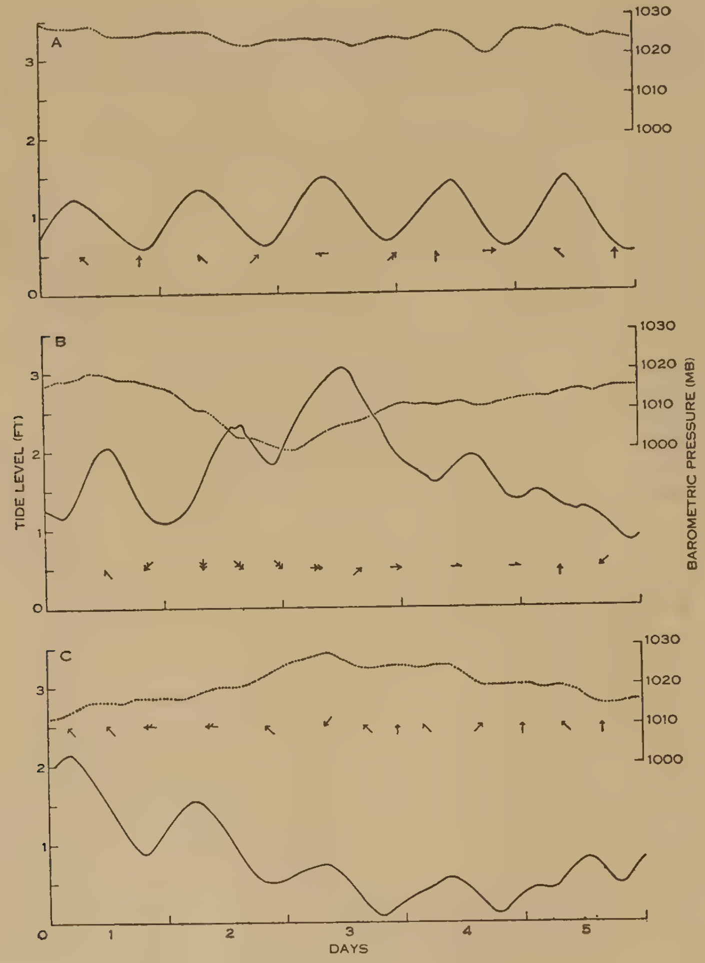

Fig. 4.—Tidal records at station No. 6, with barometric pressure and wind data from Perth Weather Bureau. *A*, summer; *B*, winter; *C*, late spring. —— Water level; •••••• barometric pressure.

Under stable barometric conditions such as are encountered in the summer months the morning easterly wind is replaced by an afternoon sea breeze.

Figure 4*A* shows the tidal record obtained at station 6 during such a period; the diurnal tidal wave remained undistorted, its amplitude was constant, and there was no significant change in mean water level.

The record obtained during the development of a cyclonic depression is shown in Figure 4*B*. In this case falling pressures were associated with a pronounced wind shift to the northern quarter, during which the diurnal tidal wave became distorted. The onshore gales characteristic of such periods had the effect of making each flood phase greater than that of the preceding ebb, so that over a period of several days there was a marked increase in the mean water level, due to the entry of sea-water from the marine end of the system. Once the depression moved further away and the wind strength was dissipated under the influence of rising barometric pressure, the ebb phase of each tidal cycle became dominant, so that the water level fell steadily as water moved out of the system.

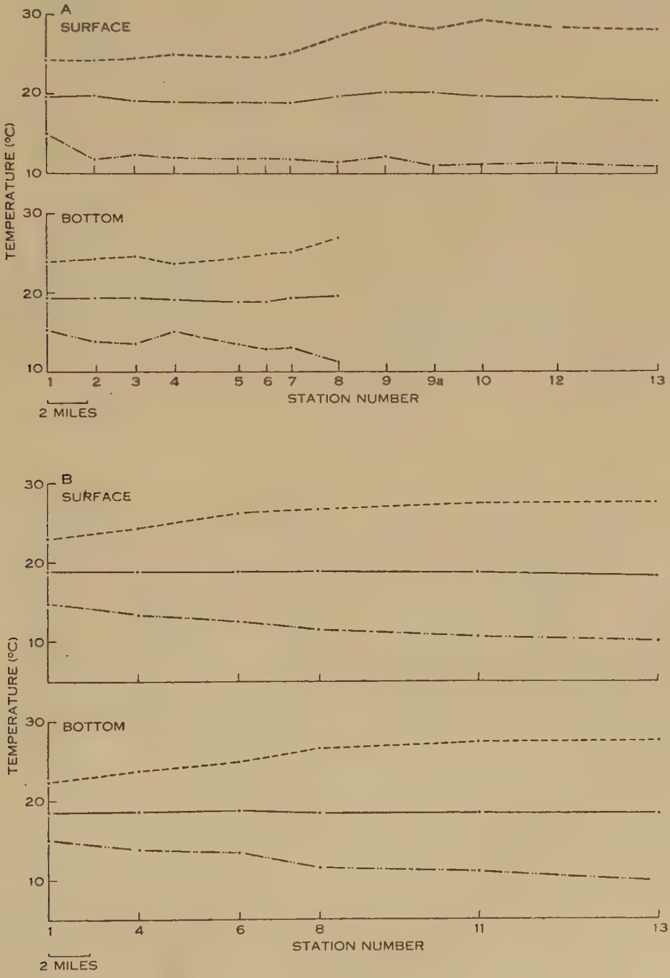

Fig. 5.—Maximum, mean, and minimum temperature values. *A*, Swan River, 1944-1952; *B*, Hawkesbury River, 1946-1951. -- • -- Maximum; —•— mean; —••— minimum.

The time interval between these depressions is usually sufficient to allow the water level within the system to return to normal. Occasionally, however, the onshore gales associated with these depressions are prolonged to such an extent that water is piled up within the system and flooding occurs. Of course excessive rainfall has the same effect, because of the fact that the discharging fresh water cannot escape to the sea with sufficient rapidity; but it is important to realize that a particular sequence of weather conditions can cause a considerable rise in water level, even though normal rainfall registrations are not exceeded.

The low water-levels observed during the late spring periods are associated with high barometric pressures and offshore winds (Section IV). The tidal record shown in Figure 4*C* was obtained in October 1954; it shows clearly how the tidal wave was distorted so that successive ebb phases became dominant, and the water level fell rapidly over a period of several days. This record also shows the development of semi-diurnal tides, the amplitude of which was appreciably reduced. The changes in hydrological conditions in the subsurface waters of the basin (Section VIII) show that this phenomenon of falling levels is not associated with freshwater discharge, which in any case is hardly significant at this time of the year.

VI. Distribution of Hydrological Properties

(*a*) *Temperature*

The maximum, mean, and minimum temperature values, calculated for all observations between 1944 and 1952, are shown in Figure 5, together with similar data obtained between 1946 and 1951 at selected stations within the Hawkesbury River, one of the principal estuarine systems of eastern Australia. The similarity between these two sets of data is rather misleading, since no indication is given of the factors responsible for the temperature ranges. The records have been subjected to a further analysis by grouping the observations at one station in each system within 1°C units; the distribution of such groups is shown in Figure 6. The stations selected, Swan River No. 5 and Hawkesbury River No. 6, are both between 9 and 10 miles from the mouths of the respective systems, and the channel depths are approximately the same (12 m).

The range of temperatures is the same in each case, but the similarity between surface and bottom distributions at the Hawkesbury River station is absent in the Swan River station, particularly at the lower end of the temperature scale. This fact suggests that, whereas in summer there may be little thermal stratification at the Swan River station, which is situated in the deep basin, temperature changes are more pronounced during the winter in the surface waters than at the bottom. On the other hand Figure 6*B* suggests that thermal homogeneity is maintained throughout the water column at the Hawkesbury River station.

An examination of the seasonal curves of temperature at the two stations in 1951 (Fig. 7) shows that thermal stratification developed at each during the winter; the chlorinity curves (Fig. 12) show that in both cases this stratification was associated with freshwater discharge. The subsequent behaviour of each system is most significant. The strongly developed tidal mixing within the Hawkesbury River enables thermal homogeneity to be established again, resulting in a comparatively rapid rise in the surface temperature and a fall in that of the bottom. On the other hand it is apparent that the heat exchanges between surface and bottom waters at the Swan River station were negligible by comparison; the temperature gradient which develops each winter under the influence of freshwater discharge is not overcome until the surface waters are subjected to vernal heating. The absence of thermal stratification during the summer months is also most significant; this feature is discussed further in Section VIII.

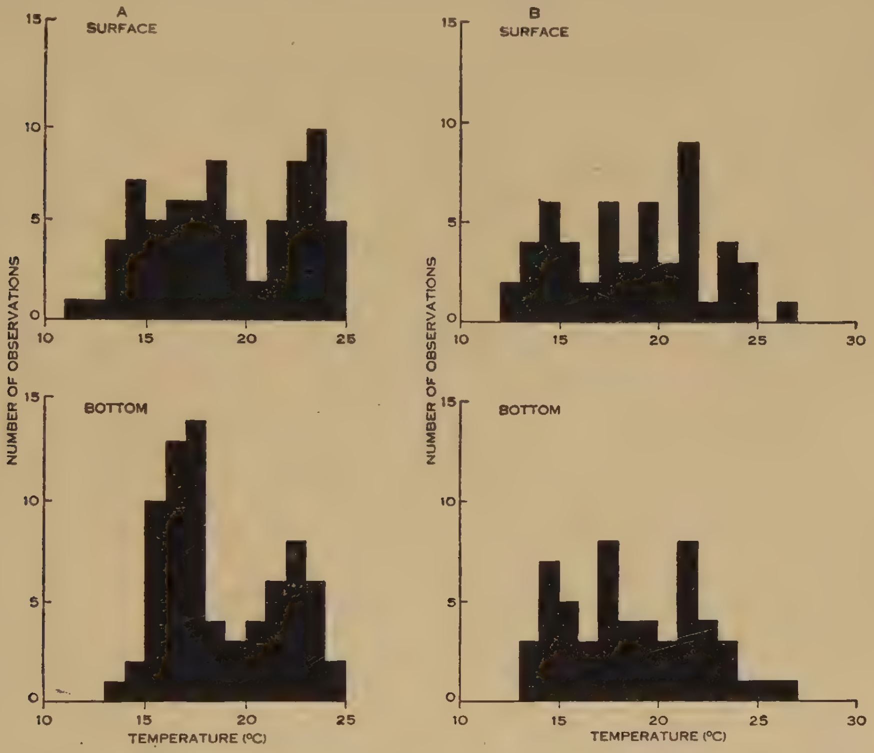

Fig. 6.—Distribution of observations of temperature. *A*, Swan River station 5, 1944-1952. Depth 12 m. *B*, Hawkesbury River station 6, 1946-1951. Depth 10 m.

The winter temperature of the bottom waters of the Swan River basin is controlled to some extent by the date of the onset of freshwater discharge. In 1953 this discharge commenced in May, and at the end of July bottom temperatures within the basin were about 17·5°C. On the other hand, in 1954 there was very little discharge before the end of July, and the same region showed temperatures of about 15·5°C. These low temperatures have been observed in other years when the discharge was delayed; they must be the exception rather than the rule, because the basin waters are normally sealed off by a freshwater layer before their seasonal cooling has reached such an advanced stage. The effect of early or late run-off must have an important influence on the subsequent deoxygenation of the bottom waters; this process is no doubt accelerated or retarded, depending on the temperature of these waters.

The temperature of the winter discharge waters lies between 12 and 14°C, and their introduction into the basin as a surface layer results in the establishment of a marked thermal gradient (Fig. 8). During the winter of 1953 it was possible, using a thermistor unit, to demonstrate a rise of 3°C within 1 ft at the boundary between fresh and salt water. Reference has already been made to the heating of the surface waters during the early spring period. Figure 9 shows the development of this process in 1953; it occurred while a considerable halocline was maintained. The establishment of a decreasing thermal gradient appears to be one of the controlling factors in the development in the surface waters of photosynthetic organisms, which account for the vernal disappearance of nutrients within the basin (Section VII).

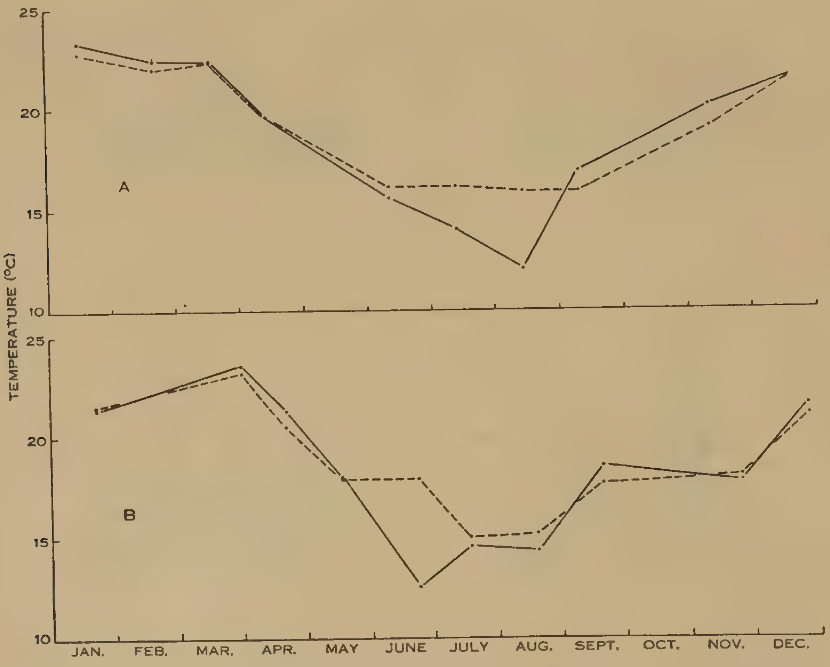

Fig. 7.—Seasonal curves of temperature in 1951. *A*, Swan River station 5. Depth 12 m. *B*, Hawkesbury River station 6. Depth 10 m. —•— Surface; --•-- bottom.

(*b*) *Chlorinity*

In Figure 10 the maximum, mean, and minimum chlorinity values at all Swan River stations from 1944 to 1952 are compared with those at selected stations within the Hawkesbury River. The minimum lines show that each system is subjected to a considerable freshwater dilution, although the Hawkesbury River displays a greater resistance to this phenomenon. The bottom minimum line for the Swan River shows that it is possible for the greater part of the basin to be completely flushed, only the region of maximum depth remaining saline. However, the proximity of the maximum and mean lines for bottom observations gives some indication of the stable nature of these waters, and suggests that their dilution by freshwater discharge may be exceptional.

The stability of the bottom waters of the Swan River basin is demonstrated quite clearly in Figure 11*A*, which shows the distribution of observations at station 5 between 1944 and 1952. Apart from a single flushing at this station in August 1946, the chlorinity of the bottom waters remained above 15‰; on the other hand, the distribution of observations at the surface shows that this region was frequently subjected to dilution by fresh water.

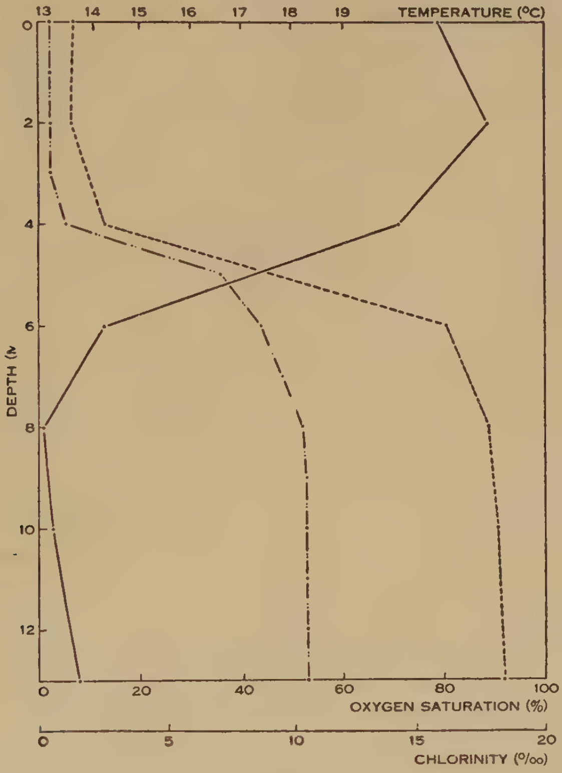

Fig. 8.—Depth profiles at Swan River station No. 4*b*, i.vii.1953. —·—··— Temperature; --·-- chlorinity; —·— oxygen saturation.

The distribution of chlorinity values observed at station 6 in the Hawkesbury River between 1946 and 1951 is shown in Figure 11*B*. There is no great difference between the surface and bottom observations, a fact which suggests that considerable vertical mixing occurs within this system, so that density stratification does not persist. The equilibrium state as defined by Rochford (1951, p. 25) is rapidly re-established in the Hawkesbury River after the surface waters are diluted by freshwater discharge. On the other hand, the poorly developed tidal energy within the Swan River means that prolonged stratification occurs under the influence of winter floods, even though the discharge volume of this system is much lower than that of the Hawkesbury River.

The seasonal curves of chlorinity for Swan River station 5 and Hawkesbury River station 6 are shown in Figure 12. The vertical homogeneity of the former during the summer months is a regular feature of the cycle, as the region is not normally subjected to summer rain (cf. Fig. 3). There is a regular response to winter discharge in the surface waters, and the resulting stratification extends over the spring period. The fall in surface chlorinity is governed by the date of commencement of discharge.

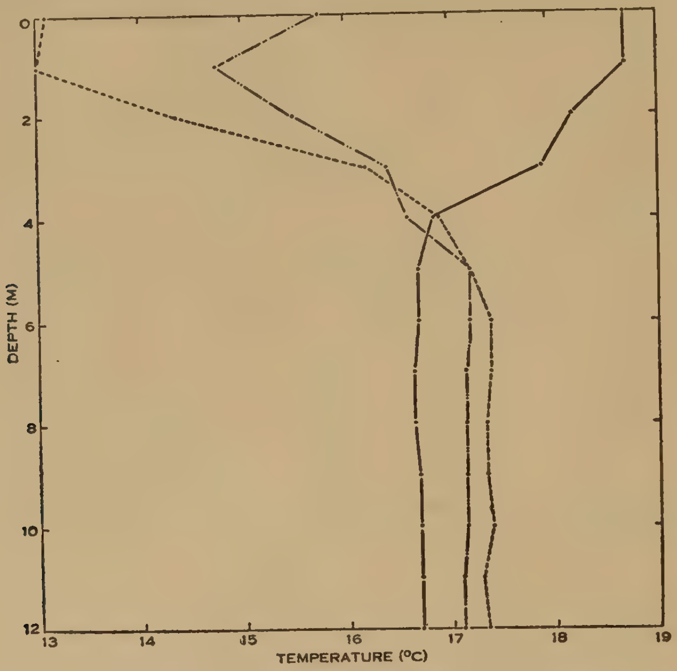

Fig. 9.—Temperature-depth profiles at Swan River station No. 5.
-- • -- 13.viii.1953; —•—••— 9.ix.1953; —•— 30.ix.1953.

The rainfall regime in eastern Australia frequently causes considerable dilution during the summer months; in 1951 the Hawkesbury River was also stratified in June, but this effect was overcome in a comparatively short time by mixing processes which are highly efficient compared with those of the Swan River. The fall in bottom chlorinity in July, associated with an increase at the surface (Fig. 12*B*), can only mean the overturn of the entire water column at this station.

The outstanding feature of the early discharge period in the Swan River basin is the establishment of a clearly defined halocline (Fig. 8), which corresponds to the thermal gradient referred to in Section VI(*a*). The existence of such a sharp boundary has always been suspected, but it was not verified until the technique of sampling at intermediate depth was adopted in 1953. It becomes more diffuse during the spring period, by which time a significant fall in freshwater discharge has occurred. The establishment of a homogeneous surface layer of higher chlorinity is considered to be an important step in the cycle of events which leads to summer homogeneity (Section VIII). It is obvious that the mechanism responsible is different from that which destroyed the pronounced gradients of temperature and chlorinity in the Hawkesbury River in the winter of 1951. The consistency of bottom chlorinity values during the winter-spring period precludes the possibility of cellular overturn such as occurs in the estuaries of eastern Australia.

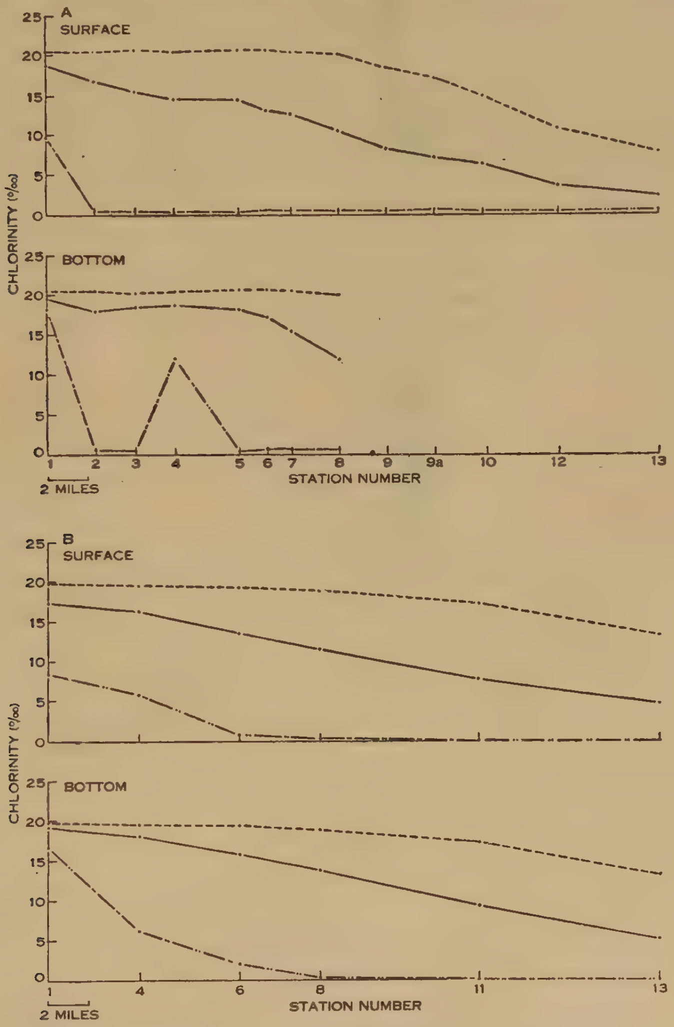

Fig. 10.—Maximum, mean, and minimum chlorinity values. *A*, Swan River, 1944-1952; *B*, Hawkesbury River, 1946-1951. -- • -- Maximum; —•— mean; —•—••— minimum.

(*c*) *Dissolved Oxygen*

The different reactions to freshwater discharge of the estuaries of south-western and eastern Australia have a profound influence on the seasonal cycle of

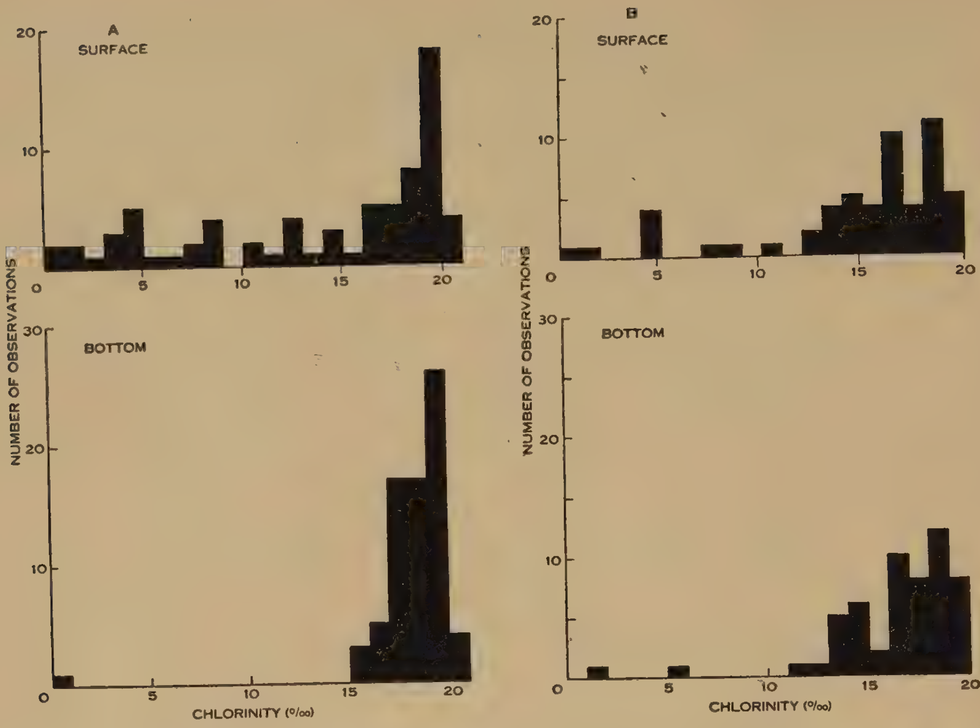

Fig. 11.—Distribution of chlorinity observations. *A*, Swan River station No. 5, 1944-1952. Depth 12 m. *B*, Hawkesbury River station No. 6, 1946-1951. Depth 10 m.

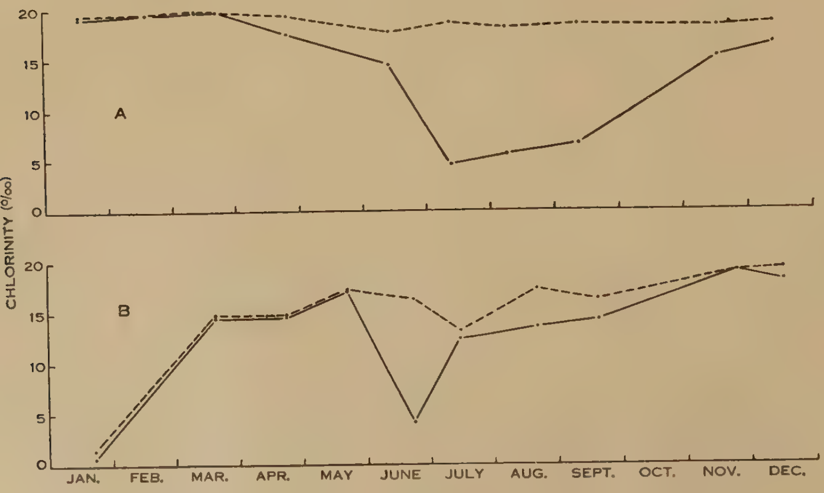

Fig. 12.—Seasonal curves of chlorinity in 1951. *A*, Swan River station No. 5. Depth 12 m. *B*, Hawkesbury River station No. 6. Depth 10 m. —•— Surface; --•-- bottom.

oxygen distribution. In Figure 13 the maximum, mean, and minimum values of oxygen saturation observed in the Swan River between 1944 and 1952 are compared with those observed at selected stations within the Hawkesbury River between 1946

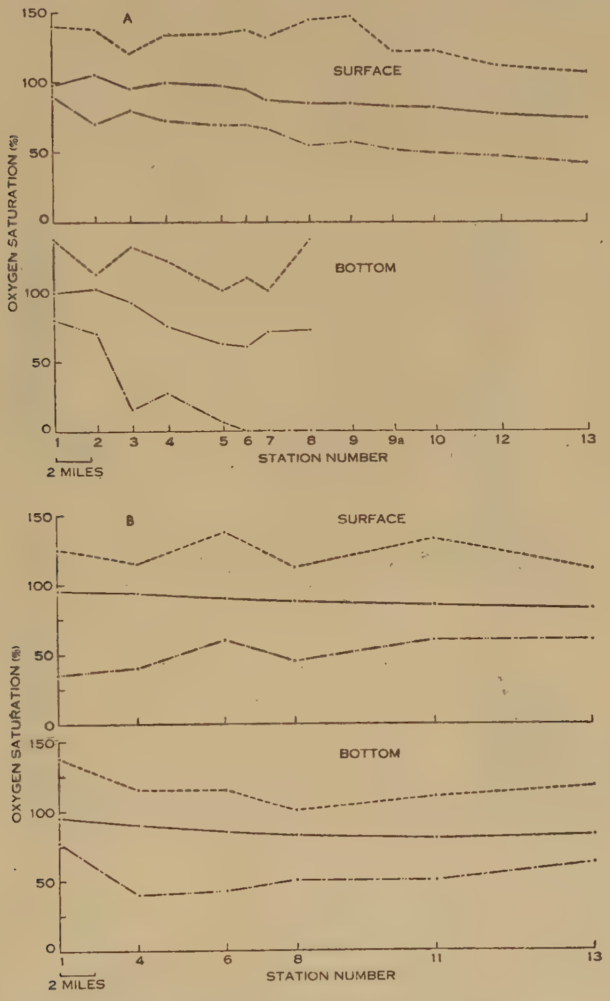

Fig. 13.—Maximum, mean, and minimum values of oxygen saturation. *A*, Swan River, 1944-1952; *B*, Hawkesbury River, 1946-1951. -- • -- Maximum; —•— mean; —•—••— minimum.

and 1951. The bottom minimum line for the former system shows that it is possible for considerable oxygen consumption to occur in the basin region, and the distortion of the mean line suggests that this process is a frequent one. On the other hand, the similarity between surface and bottom data in the Hawkesbury River is a reflection of the ability of this system to maintain comparatively high subsurface oxygen concentrations.

The distribution of observations of oxygen saturation at Swan River station 5 is shown in Figure 14*A*. The surface observations are grouped about the normal saturation value; those above this normal usually occurred in summer, whereas the lower values were caused by the oxygen demand of the silt-loaded discharge waters. The fact that more than one-third of the bottom observations lay below 50 per cent. shows clearly that there was a frequent depletion of oxygen in this region. In actual fact this depletion is a regular seasonal feature, occurring under the stratified conditions caused by winter discharge; its intensity is controlled by the nature of this discharge. The presence of a deep surface layer of fresh water can cause complete exhaustion of oxygen in the bottom waters of the upper basin. This was the case during the winter of 1953: on the other hand, the absence of a persistent and clearly defined discharge layer in 1954 meant that deoxygenation was not so intense.

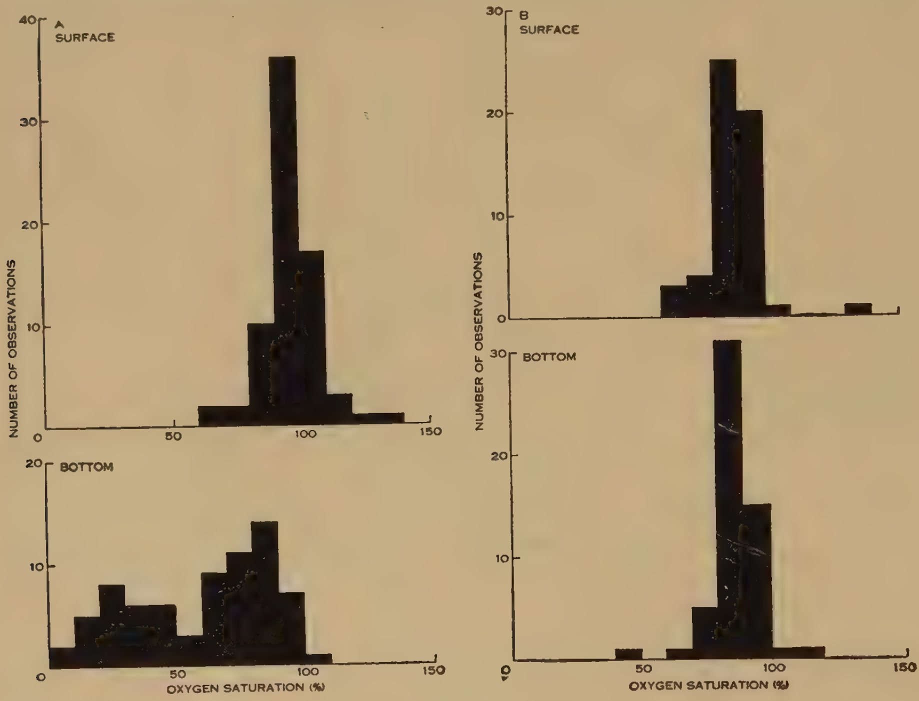

Fig. 14.—Distribution of observations of oxygen saturation. *A*, Swan River station No. 5, 1944-1952; depth 12 m. *B*, Hawkesbury River station No. 6, 1946-1951; depth 10 m.

The distribution of observations at Hawkesbury River station 6 (Fig. 14*B*) shows that the comparatively efficient mixing processes developed in this system by tidal energy tend to establish and maintain a homogeneous water column, so that there is never a prolonged oxygen lack in the bottom waters. This fact is apparent from an examination of Figure 15, which shows the seasonal cycles of oxygen within the two systems in 1951. Homogeneous conditions were maintained at the Hawkesbury River station throughout the year, except for the May period, when a value of 42 per cent. was recorded at the bottom (Fig. 15*B*). It is possible that this value was due to an analytical error, since it was not associated with a gradient of either temperature or chlorinity (Figs. 7 and 12); also the stations above and below No. 6 showed normal oxygen values. Even if the data are accepted as accurate there was a comparatively rapid return to normal values by the next sampling date. The intense stratification observed in June was not associated with oxygen depletion; even if this did develop subsequently its effect could not have been prolonged.

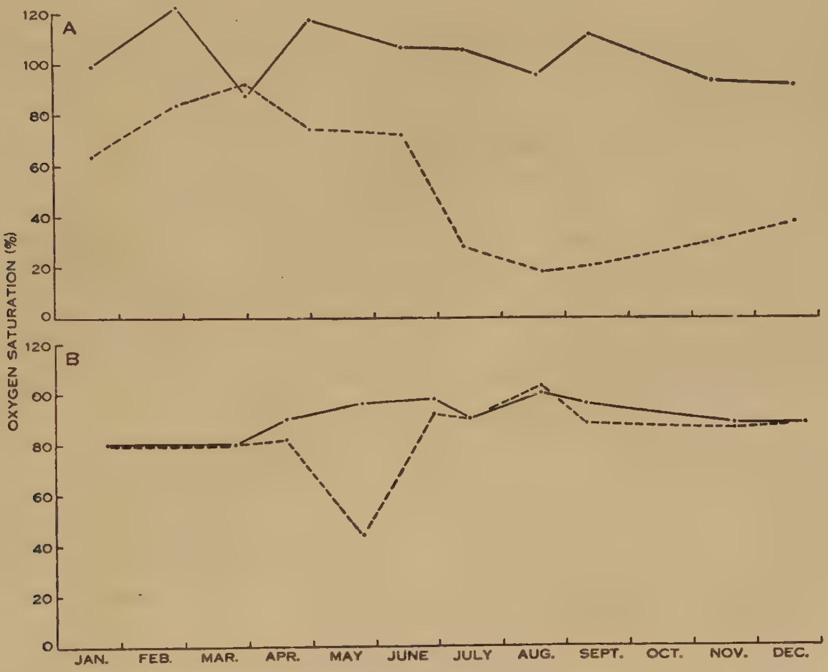

Fig. 15.—Seasonal curves of oxygen saturation in 1951. *A*, Swan River station No. 5; depth 12 m. *B*, Hawkesbury River station No. 6; depth 10 m. —•— Surface; --•-- bottom.

The outstanding feature of the seasonal curves at the Swan River station is the pronounced oxygen consumption occurring during the period of vertical density stratification (Fig. 15*A*). Each year this zone of low oxygen concentration persists at the upper end of the basin during the spring period, and it does not disappear until the region becomes marine-dominated in summer. The existence of vertical oxygen gradients during January and February 1951 is not a regular feature of the seasonal cycle; in some years the homogeneous conditions were developed by the end of December, and maintained until the commencement of winter run-off in the following year.

In 1953 the programme of sampling at intermediate depths disclosed that oxygen disappeared with considerable rapidity throughout the entire water column below the halocline (Fig. 8); on some occasions minimal values were observed at intermediate depths and not at the bottom. This fact may be due to the contribution of organic matter by the silt-loaded discharge waters, which in this particular year showed oxygen values below the saturation level. In other years, when the discharge was not so intense, the surface oxygen values did not fall below the saturation level (Fig. 15*A*), presumably because the amount of oxidizable organic matter was reduced.

In the spring of 1953 there was a pronounced rise in the oxygen content of the surface waters (Fig. 38), corresponding to the establishment of a decreasing vertical thermal gradient. The simultaneous disappearance of both phosphate and nitrate, particularly the latter (Fig. 22), indicates that increased photosynthesis was at least partly responsible for the observed increases in oxygen tension.

The consumption of oxygen in the bottom waters at the lower end of the basin is never as great as it is further upstream. In Section VIII it is shown that this fact is due to the depth contour of the basin, which allows the cascading of oxygenated marine water into the lower part. The subsequent movement of this marine water into the upper basin occurs in a bottom wedge, and the efficiency of mixing is therefore considerably decreased. The presence of this wedge accounts for the particular type of vertical oxygen profile observed during the spring of 1953, when a pronounced rise in oxygen saturation was confined to the bottom; the original desaturated basin water remained at intermediate depths (Fig. 38).

The changes in oxygen distribution observed in the basin during the intensive sampling programmes of 1953 and 1954 have been used to follow the recovery cycle from the development of stratification through to the establishment of homogeneous summer conditions. As the oxygen content of the basin subsurface waters is very low compared with that of the incoming marine water, it is possible in many cases to follow the movement of the latter by using oxygen as an identifying agent without reference to any other hydrological property. The results of employing this technique are discussed further in Section VIII.

(*d*) *Hydrogen Ion Concentration*

An intensive sampling programme was carried out at station 6 in 1951 and 1952, in an endeavour to follow the seasonal variations of pH, particularly during the period when the area was affected by winter discharge. Figure 16, a scatter diagram, shows the relation between oxygen saturation and pH in the bottom waters at station 6. The correlation between these two properties shows that there was a considerable fall in pH wherever oxygen values fell, i.e. when the system reached a stratified state.

The seasonal curves during these two years for pH in both the surface and bottom waters at station 6 are shown in Figure 17. Notwithstanding the considerable short-term variations of the surface waters, the following points are apparent:

(i) The fall of pH occurs early in the period of discharge; in 1952 low pH values were maintained until mid November, when the halocline began to disappear. Because of the less intensive run-off in 1951, the rise in pH occurred much earlier in that year.

(ii) Maximal pH values were observed in the surface waters in September, a fact which can be correlated with other hydrological and biological factors mentioned previously.

(iii) Small pH differences were observed between surface and bottom during the summer months; this was to be expected from the homogeneity of other hydrological components.

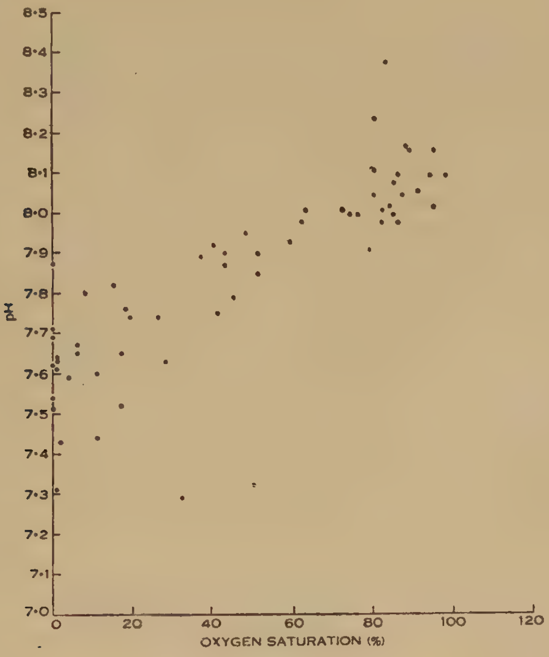

Fig. 16.—Relationship between pH and oxygen saturation in the bottom waters at Swan River station No. 6, 1951-1952. Depth 6 m.

There is little doubt that the short-term variations in the pH of the surface waters during the discharge period are at least partly due to analytical errors; considerable difficulty has been encountered in determining the pH of poorly buffered water. For this reason no significance can be placed on these changes; on the other hand, the bottom values can be accepted without hesitation because of the maintenance of high chlorinity in the region, notwithstanding considerable seasonal fluctuations at the surface.

VII. Nutrient Cycles

The sampling programme within the Swan River basin was intensified during the winter-spring period of 1953 and 1954 with two main objectives in mind. One of these was to use the observations of temperature, chlorinity, oxygen saturation, and nutrient salts to explain the circulatory processes by which the highly stratified basin returned to the homogeneous conditions which characterize the summer period. The other was to examine more closely the changes in nitrates and phosphates, and to assign biological or circulatory significance to these changes. In this section the results of the latter objective are discussed, together with the distribution and annual cycles of these nutrient salts.

Some caution should be exercised in comparing nutrient cycles in different estuarine systems, since the contribution of phosphate or nitrate by freshwater discharge depends so much on the particular environment; it is affected by such factors as the size of the catchment area, the type of soil, and the amounts of agricultural and industrial effluents. Indeed, it is conceivable that changes in the latter factor could introduce completely new features into the nutrient cycle in a comparatively short period.

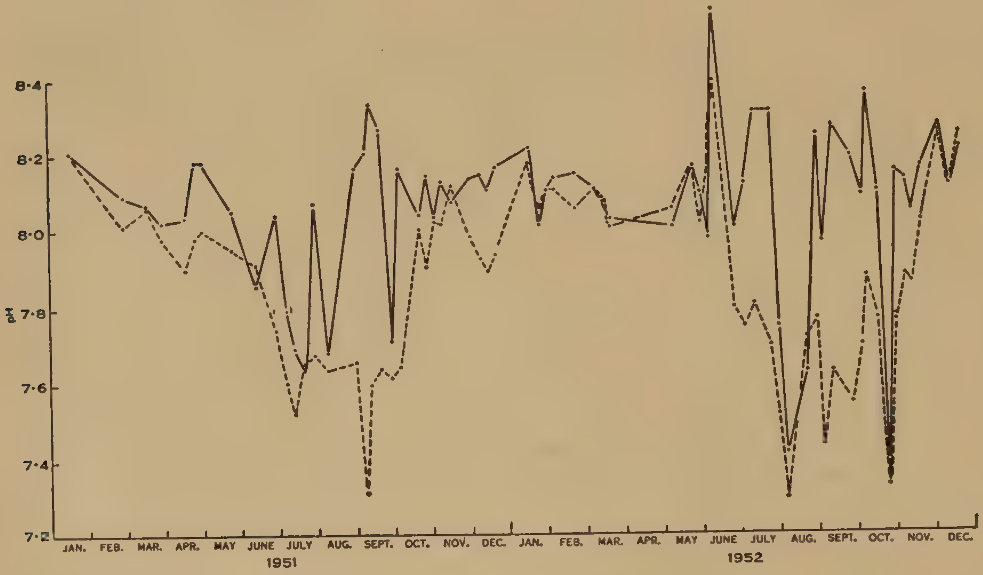

Fig. 17.—Seasonal curves of pH at Swan River station No. 6, 1951-1952. Depth 6 m. —•— Surface; --•-- bottom.

Within the estuary itself the distribution of both nitrates and phosphates is controlled by biological as well as circulatory processes, and it is desirable to have some knowledge of the relative significance of each factor. With this knowledge it may be possible to make some limited comparisons with other estuarine systems.

(*a*) *Nitrate Nitrogen*

Figure 18 shows the maximum, mean, and minimum values of nitrate nitrogen for all stations between 1947 and 1952. The proximity of the mean and minimum lines suggests that the level of nitrate is generally low, particularly in the basin region. This suggestion is verified in Figure 19, which shows the distribution of observations at station 5. More than half of these were zero, both at surface and bottom, and it is therefore apparent that the supply of nitrate is often exhausted, either temporarily or for prolonged periods.

This absence of nitrate is associated with the marine domination of the basin during the summer months (Fig. 20). Data obtained from the shallow coastal waters of south-western Australia (Spencer 1952) show that minimal concentrations of nitrate persist in this region throughout the year, although phosphate values may rise to 20 μg per litre; an anomalous $NO_3 : PO_4$ ratio is thus produced. No significant contribution of nitrate is therefore made from the marine end of the system, which always acts as a diluting agent.

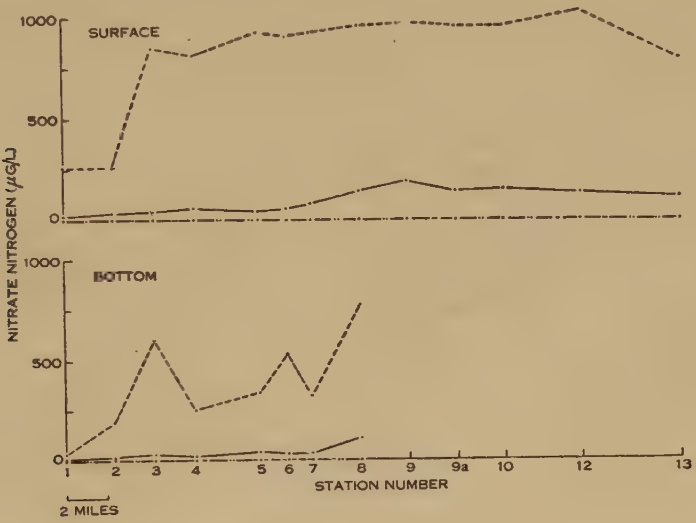

Fig. 18.—Maximum, mean, and minimum values of nitrate nitrogen at all Swan River stations, 1947-1952. -- • -- Maximum; —•— mean; —•——••— minimum.

On the other hand the seasonal curves shown in Figure 20 indicate that some contribution of nitrate is made each year during the winter months. The surface values vary considerably from year to year, and do not necessarily reflect the intensity of freshwater discharge. For example, values of 500 μg nitrate nitrogen per litre were observed during the winter of 1954; this concentration is comparable with the maximum observed in 1953 (700 μg nitrate nitrogen per litre) when the intensity of freshwater discharge was far greater than in 1954. Beyond a certain point further run-off may act as a diluting rather than a contributing factor.

The intensive sampling programme carried out during the winter-spring period of 1953 helped to explain several features of nitrate distribution.

(i) *Winter Period.*—In mid July 1953 a concentration of about 600 μg nitrate nitrogen per litre was observed throughout the surface water of the basin. However, the depth profiles of nitrate at stations 3*a* and 5 on July 17 (Fig. 21) showed a marked contrast in conditions below the halocline. At station 3*a* the subsurface oxygen saturation values lay between 10 and 20 per cent., and a considerable production of nitrate had occurred in this region (Fig. 21*A*). This nitrate may be derived from the decomposition of organic nitrogen within the subsurface waters, or from the contribution of nitrate as such from the nutrient-rich discharge waters.

At the upper end of the basin (Fig. 21*B*) oxygen had completely disappeared from the subsurface waters, and no accumulation of nitrate had yet occurred in this region. Apparently any nitrate contributed from the surface waters was being reduced in the subsurface waters, while the decomposition of organic nitrogen could not proceed to the nitrate stage because of the absence of oxygen.

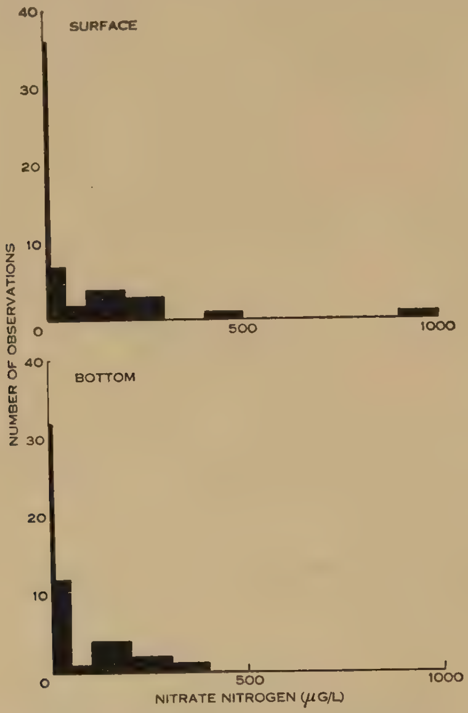

Fig. 19.—Distribution of observations of nitrate nitrogen at Swan River station No. 5, 1947-1952. Depth 12 m.

The subsequent nitrate cycles at stations 3*a* and 5 are also shown in Figure 21. At the former station the subsurface waters were affected by the entry of marine water, the initial penetration occurring at intermediate depths (cf. Section VIII). By the beginning of August the whole of the hypolimnion showed low nitrate concentrations.

During the same period nitrate was increasing in the subsurface waters at the upper end of the basin (Fig. 21*B*), although the peak of phosphate production had already passed (Figs. 26 and 27*B*). There is obviously a time lag between the formation of phosphate and that of nitrate, so that their proportions vary considerably at different stages of the cycle. The rise in nitrate concentration at station 5 during July 1953 was greater at first in the bottom waters than at intermediate depths, suggesting that nitrification was more pronounced at the mud-water interface. During this period the oxygen saturation did not rise above 5 per cent., but even such a slight increase was apparently sufficient to ensure the production of nitrate.

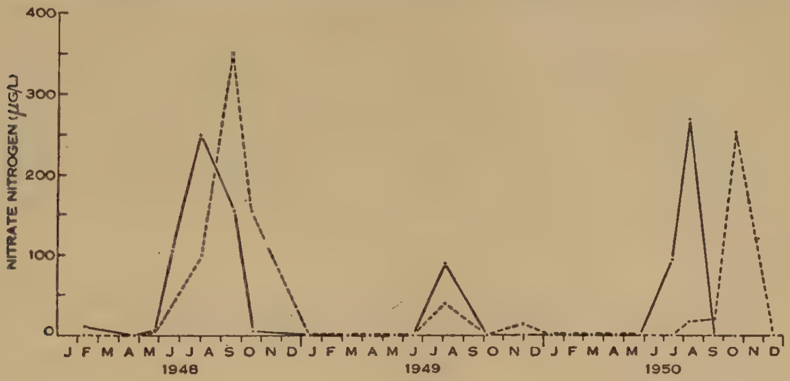

Fig. 20.—Seasonal curves of nitrate nitrogen at Swan River station No. 5, 1948-1950. Depth 12 m. —•— Surface; --•-- bottom.

(ii) *Spring Period.*—A pronounced fall in surface nitrate values was observed throughout the basin in early September 1953 (Fig. 22*A*). Figure 22*B* shows how inorganic phosphate was also disappearing during the same period, and there is little doubt that both these phenomena were caused by the development of photosynthetic organisms in the surface waters.

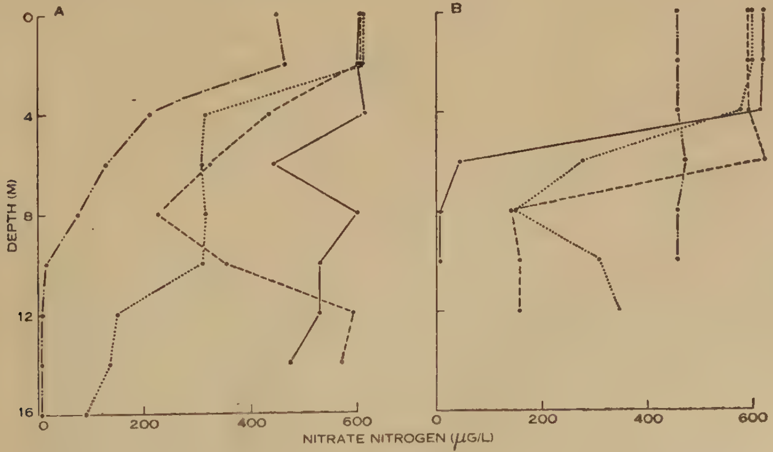

Fig. 21.—Nitrate-depth profiles. *A*, At Swan River station No. 3*a*; *B*, at Swan River station No. 5. —•— 17.vii.1953; --•-- 22.vii.1953; •••••• 30.vii.1953; —•—••— 5.viii.1953.

The distribution of nitrate at station 4*a* on September 9 (Fig. 22*A*) shows the presence of three distinct zones. In the surface zone nitrate was disappearing while at intermediate depths the zone of maximum deoxygenation still persisted, with high nitrate concentrations. The bottom zone was now being affected by the movement upstream of marine water as a bottom wedge (cf. Section VIII), so that nitrate concentrations were considerably lower than in the intermediate zone, while the oxygen tension was considerably higher.

Nitrate continued to disappear from the basin waters during the latter half of September, and by the end of the month it was completely exhausted, owing to the combined effect of biological utilization and circulatory dilution by nitrate-deficient marine water. However, phosphate maxima persisted in the bottom waters of the basin long after the end of September (Fig. 28); this fact is discussed in Section VII(*b*).

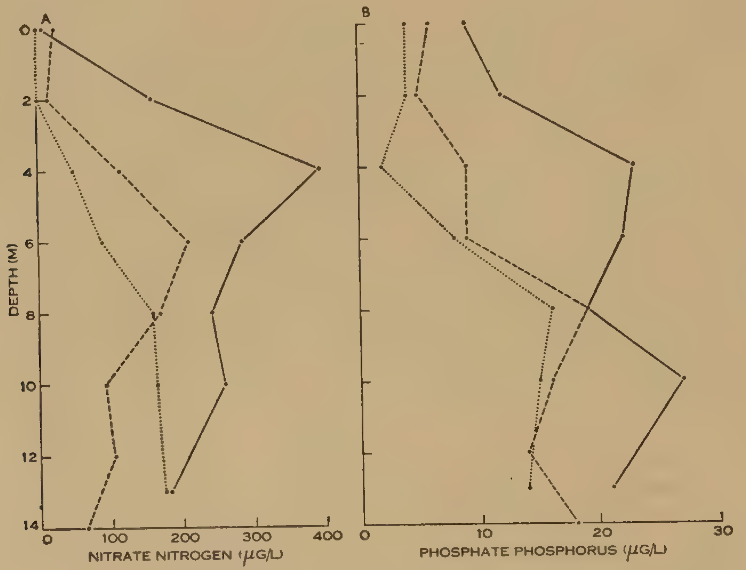

Fig. 22.—Depth profiles at Swan River station No. 4*a*. *A*, of nitrate nitrogen; *B*, of phosphate phosphorus. —•— 2.ix.1953; --•-- 9.ix.1953; •••••• 16.ix.1953.

In 1954, a year of low rainfall and poorly developed stratification, no large-scale production of nitrate was observed in the subsurface waters of the basin. The oxygen tension of these waters was maintained at a much higher level than in 1953, even at the upper end of the basin; and it is possible that under those conditions there was no appreciable decomposition of organic nitrogen in the subsurface waters.

In August 1954 the nitrate concentration in the surface waters was high because of freshwater discharge; if this nitrate were being contributed to the subsurface waters it should have accumulated there, as the oxygen saturation of 20 per cent. should have prevented its reduction to ammonia or even to nitrogen. The fact that no appreciable accumulation of nitrate was observed in the subsurface waters at this stage suggests that the surface waters did not make any appreciable contribution of nitrate to the subsurface zone.

The rapid disappearance of both nitrate and phosphate from the surface waters of the basin in the early spring of 1954 is clearly demonstrated in Figure 23;

the extent of the vernal development of photosynthetic organisms may well be controlled by the concentration of these nutrient salts in the winter discharge waters.

The part played in the nitrogen cycle of the basin waters by components other than nitrate must remain unknown for the present. The method of Kruse and Mellon (1952) for the determination of ammonia, using a pyridine-pyrazolone reagent, is at present under examination. If this method is successful the investigation of seasonal changes in ammonia distribution should prove a highly profitable line of future research.

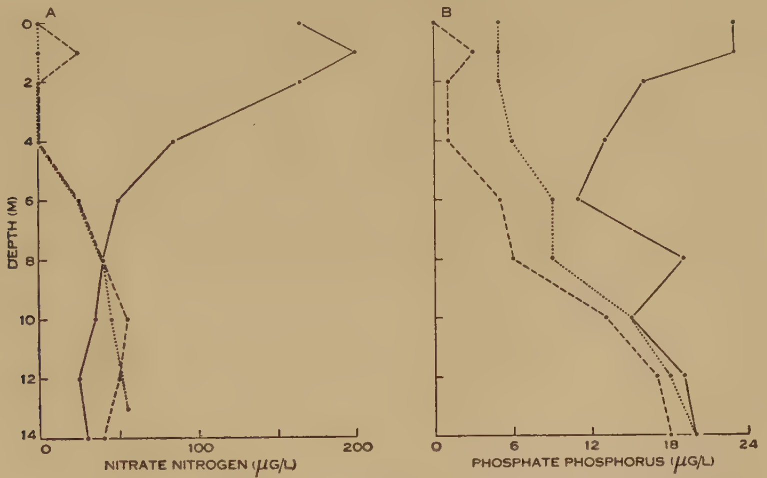

Fig. 23.—Depth profiles at Swan River station No. 4*a*. *A*, of nitrate nitrogen; *B*, of phosphate phosphorus. —•— 26.viii.1954; --•-- 15.ix.1954; •••••• 29.ix.1954.

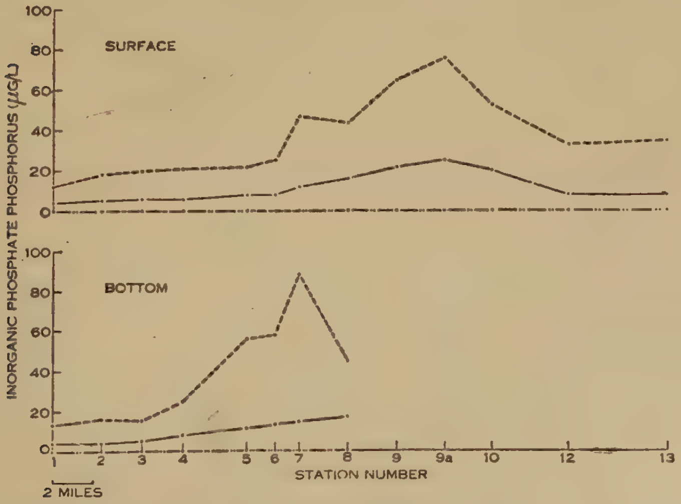

Fig. 24.—Maximum, mean, and minimum values of phosphate phosphorus at all Swan River stations, 1947-1952. --•-- Maximum; —•— mean; —•—••— minimum.

(*b*) *Phosphorus*

Figure 24 shows the maximum, mean, and minimum values of inorganic phosphate at all stations between 1947 and 1952. The peaks in the surface maximum and mean lines at station 9*a* suggest that a considerable local contribution of phosphate is made to the surface waters of the system within the region under investigation. This effect is possibly due to the existence of an industrial area around station 10.

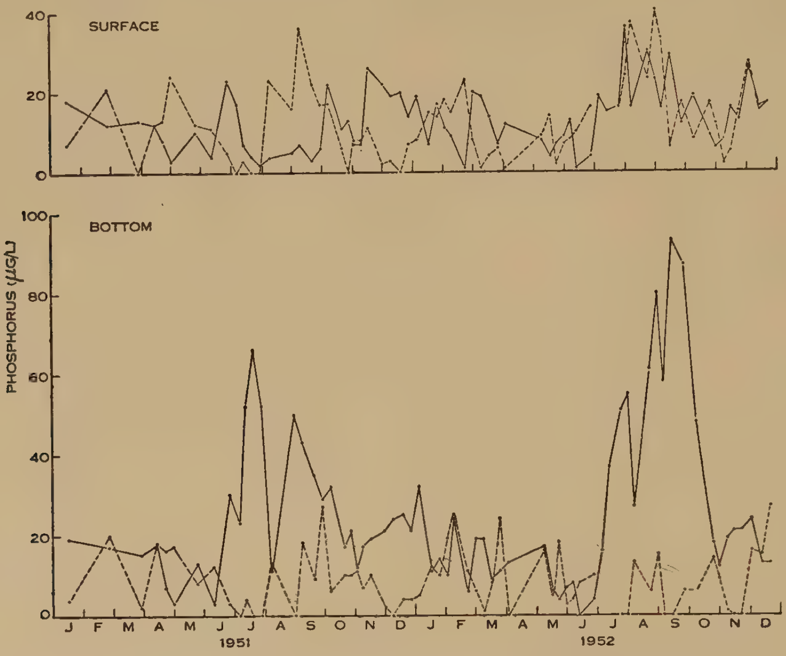

Fig. 25.—Seasonal curves of phosphorus at Swan River station No. 6, 1951-1952. Depth 6 m. —•— Inorganic phosphate P; --•-- organic P.

From the hydrological point of view the high bottom maxima observed at the upper end of the basin are very significant. These values are considerably higher than those observed in the surface waters over the same period, and they suggest a greater annual turnover of phosphorus in the bottom waters. At the lower end of the basin the subsurface production of phosphate is never so pronounced, in view of the comparatively rapid penetration of marine water, which is low in phosphate.

The seasonal cycles of inorganic and organic phosphorus at station 6 during 1951 and 1952 are shown in Figure 25. The frequency of sampling at this station makes possible a fairly detailed examination of the variations in these two constituents during various periods of the year.

(i) *Summer-Autumn Period.*—Under the homogeneous conditions prevailing during the summer and autumn there is very little difference between the phosphorus cycles observed at the surface and bottom. The high levels established during the early summer period are probably associated with the increased algal growth and mortality which occurs in the shallow banks in the upper basin during this period.

The disappearance of inorganic phosphate during the autumn can be attributed to biological utilization, but it is difficult to understand why the total phosphorus levels also remain low at the same time. It is possible that phosphorus is removed from the basin waters because of its adsorption by the bottom muds, but there is no evidence to suggest that such a process does actually occur.

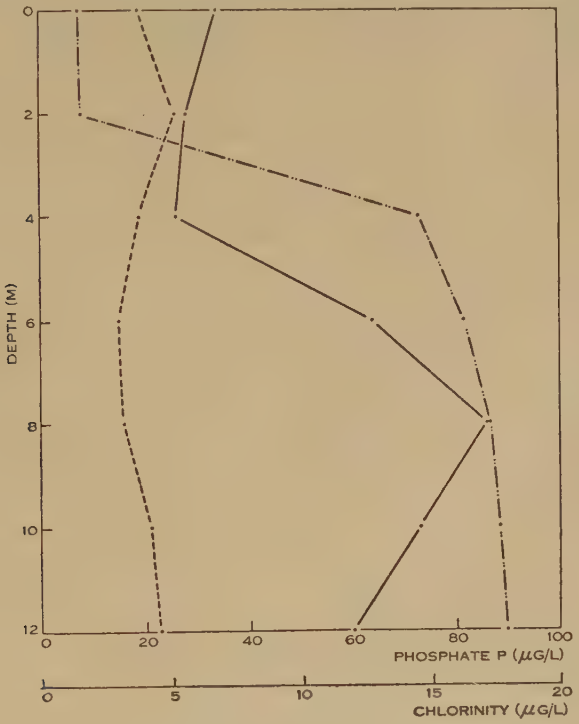

Fig. 26.—Phosphorus-depth profile at Swan River station No. 5, 8.vii.1953. —•— Inorganic phosphate P; --•-- organic P; —•—••— chlorinity.

(ii) *Discharge Period*.—The amount of phosphorus introduced into the surface waters of the basin by the discharge layer varies considerably from year to year. The high inorganic phosphorus concentration observed at the beginning of the discharge period in 1951 was not maintained and there was no contribution of organic phosphorus; on the other hand, the more intense and prolonged run-off which occurred in 1952 brought with it high concentrations of both inorganic and "organic" phosphorus. The latter is probably associated with the silt load, and no doubt some part of it consists of insoluble inorganic phosphates.

In the bottom waters the development of anaerobic conditions during winter discharge is associated with the production of very high concentrations of inorganic phosphate (Fig. 26); the relatively low concentrations of organic phosphorus observed at the same time suggest that this production is at least partly due to the decomposition of organic material.

There is a possible relationship between the amount of phosphorus present in the discharge waters and the concentration of inorganic phosphorus observed in the bottom zone at station 6. In other words the discharge waters may make some contribution of phosphorus to the subsurface waters of the upper basin. This process must occur in an indirect manner, since there is a negligible circulatory exchange between the two zones at the height of discharge. The intensive sampling programme carried out in 1953 showed that the subsurface production of phosphate at the upper basin stations was very high during the discharge period of this year; this process is demonstrated clearly in Figure 26, which shows the vertical distribution of phosphorus in its inorganic and organic forms at station 5 on July 8, together with the chlorinity profile on the same date.

Whereas the concentration of organic phosphorus was constant throughout the water column, maximum values of the inorganic form were observed at intermediate depths below the halocline, indicating that a contribution of phosphorus was being made to this region from some external source. No doubt the phosphorus present in the subsurface waters prior to the onset of stratification was largely converted into the inorganic form under the anaerobic conditions which developed. However, the observed concentrations of phosphate were so high that they could not be produced by this process alone. Reference has already been made to the comparatively low levels of total phosphorus present in both the surface and bottom waters during the pre-discharge period; in view of the homogeneous conditions prevailing in the system at this time, the assumption can justifiably be made that the intermediate waters behave in the same way. These waters were sampled during the autumn of 1954, during which time no total phosphorus values ever exceeded 30 μg per litre; these concentrations are comparable with those observed in other years when surface and bottom samples only were collected. Unfortunately, there was no large-scale production of phosphate during the subsequent winter period, and the object of the autumn sampling was somewhat defeated. Nevertheless, the available data for other years strongly suggest that phosphate is contributed to the subsurface waters from some external source.

The bottom mud itself must be considered as a possible source of phosphate. The high concentrations observed in the bottom waters at station 6 in 1951 and 1952 (Fig. 25) could have been caused by the release of phosphate from the mud, associated with the disappearance of oxygen and a fall in pH. Such a theory would also explain the absence of the organic form at the same time; however, it cannot account for the presence of intermediate maxima at station 5 on a number of occasions during the discharge period of 1953 (Figs. 26, 27*B*).

There is a distinct possibility that in this latter year considerable amounts of phosphorus were contributed to the subsurface waters from the silt-loaded discharge layer. Some process of coagulation must occur at the boundary of this layer and the saline water below, thus providing a supply of phosphorus as the silt is precipitated into the intermediate depths. Even if phosphorus were present in the silt in some organic form it would be decomposed in the stagnant waters below the halocline; this would explain why organic phosphorus did not accumulate in the subsurface waters while the inorganic values were increasing.

In 1953 considerable production of inorganic phosphate also occurred in the subsurface waters at the lower end of the basin (Fig. 27) although the concentrations were appreciably lower than those observed at the upper end. This process is also dependent on the development of stagnant conditions, but is complicated by the fact that the region is affected by the entry of marine elements to a far greater extent than the upper basin. This influence is demonstrated clearly in Figure 27, which compares the changes in the phosphate profile at stations 3*a* and 5 during the latter part of July 1953. Initially the penetration of nutrient-deficient marine water occurred at intermediate depths below the halocline (cf. Section VIII), so that minimal values were observed at about 8 m on July 22. Subsequently, the persistent entry of marine water continued to reduce the phosphate concentration throughout the hypolimnion. The absence of such changes in the corresponding vertical profiles at station 5 (Fig. 27*B*), where the subsurface maxima were maintained, shows that this region remained unaffected during the early stages of marine invasion.

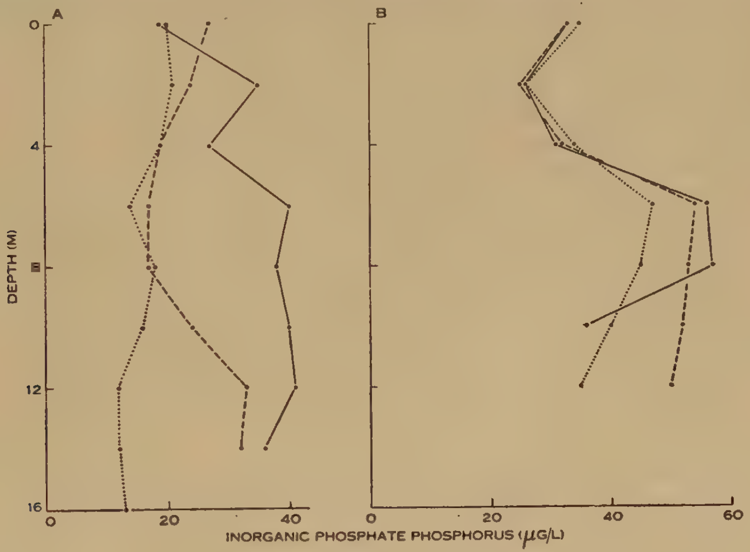

Fig. 27.—Phosphate-depth profiles. *A*, at Swan River station No. 3*a*; *B*, at Swan River station No. 5. —•— 17.vii.1953; -- • -- 22.vii.1953; •••••• 30.vii.1953.

In view of the rapidity with which the lower basin waters are ventilated in the latter stages of the discharge period, the subsurface production of phosphate is not a persistent feature of the seasonal cycle. Monthly observations at stations 3 and 4 in previous years seldom showed high concentrations of phosphate in the bottom waters; even if these did develop in the interval between these monthly samplings, they could not persist as they do further upstream.

(iii) *Spring Period.*—During the early spring period there is a marked fall in the level of inorganic phosphate in the surface waters (Fig. 25); the associated increase in organic phosphorus indicates an increase in biological activity. This utilization of phosphate was most apparent in 1951 when the surface chlorinity commenced to rise at the end of August. In 1952 the discharge period extended to the end of September, after which the fall in inorganic phosphate occurred. The development of green algae and other photosynthetic organisms in the surface waters may be delayed if the low temperature and chlorinity of these waters are maintained beyond the end of winter.

In 1953 the disappearance of both phosphate and nitrate from the surface waters of the basin had commenced by the end of August. This process continued during September (Fig. 22*B*) and was associated with a significant increase in both chlorinity and temperature, as well as the development of oxygen values well above the saturation level.

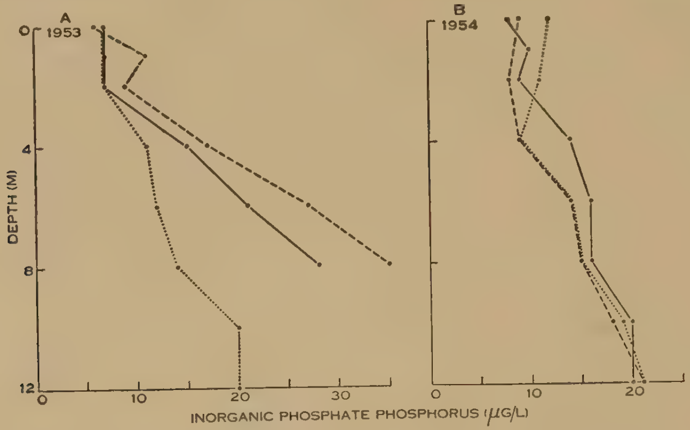

Fig. 28.—Phosphate-depth profiles at Swan River station No. 5.

A —•— 16.x.1953		*B* —•—	7.x.1954
--•--	6.xi.1953	--•--	17.xi.1954
••••••	18.xii.1953	••••••	2.xii.1954

Although in this particular year nitrate had disappeared completely from the basin waters by the end of September, the increasing vertical gradient of inorganic phosphate at the upper end was maintained well beyond this stage; indeed it was still evident in November and December (Fig. 28*A*). These facts lend some support to a theory of phosphate generation from the bottom muds, such as that proposed by Mortimer (1941, 1942). If the observed phosphate had been derived from some organic source in the water it seems logical to assume that it would also be accompanied by nitrate, since the comparatively high oxygen tension would encourage rather than hinder the completion of the nitrogen breakdown cycle. In view of the frequency of sampling, allowance can be made for a possible time lag between formation of phosphate and nitrate.

Because of the lack of persistent stratification in 1954 the deoxygenation of the subsurface basin waters was slight compared with that observed in the previous year. For this reason no significant production of phosphate was observed; however, it is interesting to note that two other features of the 1953 recovery cycle were repeated in this year. Firstly, phosphate disappeared from the surface waters during the early spring period (Fig. 23*B*), under conditions of temperature and chlorinity comparable with those prevailing at the corresponding stage of 1953. Secondly, maximum values were frequently observed in the bottom waters of the upper basin during the late spring (Fig. 28*B*).

VIII. Circulatory Features of the Basin

The circulatory features of the Swan River basin can be divided into several seasonal groups:

- (*a*) Summer-autumn period.
- (*b*) Winter-spring period:
    - (i) Stratification and subsurface deoxygenation due to commencement of winter rains and freshwater discharge.
    - (ii) Recovery cycle:
        - (1) Reduction in the intensity of freshwater discharge.
        - (2) Formation of "sill" water.
        - (3) Cascading of marine water into lower basin.
        - (4) Hydrological significance of changes in mean water level within the basin.
        - (5) Internal wave formation.

(*a*) *Summer-autumn Period*

The summer-autumn period can be considered as one in which the basin becomes virtually an arm of the sea, with a negligible contribution of fresh water from the riverine end. The hydrological properties of the basin waters are practically identical with those of the adjacent coastal waters, and there are no significant vertical or horizontal gradients within the basin.

No intensive study has yet been made of summer circulation; however, the distribution of temperature observed during 1954 (Fig. 29) shows that the basin does not develop a pronounced thermocline during this period. This fact is rather surprising, in view of the sustained solar radiation and the sluggish movement of surface waters within the basin. It suggests that some circulatory mechanism is present which overcomes the tendency of the surface waters to become heated more rapidly than the subsurface waters.

One possible explanation of such a mechanism is a type of cellular overturn, similar to that proposed by Rochford (1951) for the estuaries of eastern Australia. However, such a process derives its energy from tidal flow; and since the latter is so poorly developed in the Swan River it can be discounted as the reason for thermal homogeneity during the summer-autumn period. This homogeneity is more likely to be caused by wind-stirring than anything else, since the south-westerly winds are most consistent during the summer months (Section IV(*b*)). Although the wind data in Table 3 indicate a daily reversal of wind from an easterly to a south-westerly direction, the former is usually a light wind, whereas the sea breeze blows with greater intensity. Under these conditions it is conceivable that a wind-generated mechanism is set up which greatly assists the circulation of the basin waters and thus maintains thermal homogeneity. Occasionally the sea breeze is absent for several days, when the region is dominated by warm easterly winds. Under these conditions the air temperature rises to about 100°F and it is possible that an appreciable thermocline develops in the basin. As no intensive programme of temperature recording has been undertaken during such a period this theory cannot be confirmed at present.

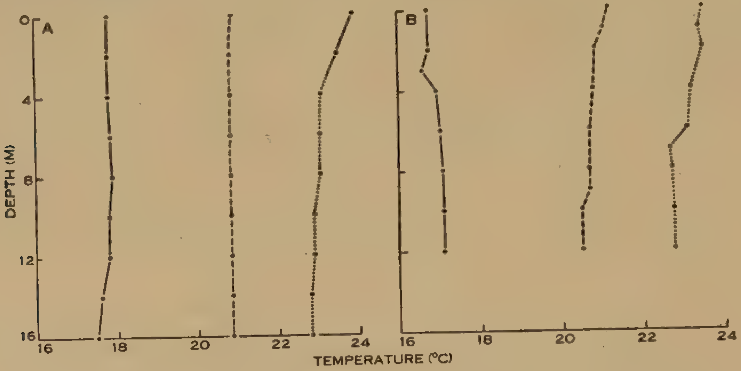

Fig. 29.—Temperature-depth profiles. *A*, at Swan River station No. 3*a*; *B*, at Swan River station No. 5. ······ 5.ii.1954; -- • -- 7.iv.1954; —•— 25.v.1954.

(*b*) *Winter-spring Period*

The essential features of the circulatory processes occurring within the basin during this period are summarized in Figure 30. If the depth of the discharging surface layer exceeds 5 m (the sill depth) the subsurface waters of the basin become deoxygenated (Fig. 30*A*). Once the intensity of discharge decreases, the depth of the surface layer in the sill region is reduced by the entry of marine water. Considerable mixing occurs between these two components; the resultant "sill" water has a density less than that of the basin bottom waters, and therefore moves upstream at intermediate depths (Fig. 30*B*). As the marine component of this "sill" water increases at the expense of the freshwater component its density increases, until it cascades into the deep waters of the lower basin (Fig. 30*C*); the subsurface waters of this region are now essentially marine in their hydrological characteristics, and the zone of oxygen depletion is confined to the upper basin.

Figure 30*C* shows also the movement of marine water beyond station 4 as a bottom wedge, and the development of internal waves which cause a further reduction in the depth of the surface layer. Although the effectiveness of these circulatory mechanisms is influenced by changes in the water level of the basin (Section V), nevertheless they bring about the domination of the basin by marine elements (Fig. 30*D*). The last trace of the zone of oxygen depletion is found in the bottom waters around station 5, before it is ultimately dispersed and homogeneous summer conditions are established once more.

(i) *Stratification and Deoxygenation*.—The hydrological properties of the winter discharge waters have already been discussed (Sections VI and VII). The depth of the surface layer within the basin varies according to the intensity of run-off; in 1953 its maximum observed depth was about 5 m, whereas in 1954, a year in which the rainfall was below average, the diluted surface layer was never observed at a depth greater than 2 m.

Since the maximum channel depth in the sill region, between stations 2 and 3, is 5 m, it is possible for the surface layer to occupy the whole of this area (Fig. 30*A*). Providing the intensity of freshwater discharge is sufficient to produce a layer of at least this depth, the subsurface waters of the basin are sealed off from the marine end of the system, and the oxygen desaturation which develops at the upper end of the basin extends to the lower end. Below the sill considerable tidal energy is expended in mixing processes between the discharging surface layer and incoming marine water.

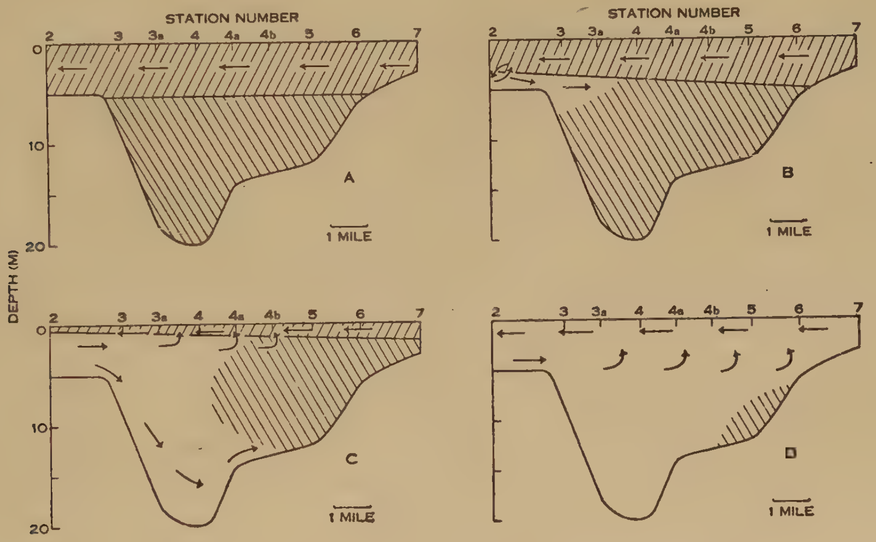

Fig. 30.—The recovery cycle within the Swan River basin.

▨ Surface discharge layer.

☰ Deoxygenated basin water.

☐ Marine water.

In a year such as 1954, when the depth of the surface layer did not approach 5 m, the link between marine and basin water remains unbroken, and stagnant conditions do not develop in the subsurface waters of the lower basin.

At those stations on the upstream slope of the basin, stations 4*a*, 4*b*, 5, and 6, there is always some disappearance of oxygen once the surface layer develops. The deeper the latter penetrates the more effectively are the bottom waters sealed from the surface, and the more intense is the consumption of oxygen. In 1953 the subsurface basin waters at station 5 became completely anaerobic during the initial discharge phase, a condition never observed during 1954.

(ii) *The Recovery Cycle.*—As stated in Section VII, one of the objectives of the intensive sampling programmes carried out in the basin in the winter-spring periods of 1953 and 1954 was to study some of the factors responsible for the ultimate establishment of the homogeneous conditions which characterize the summer period. The sequence of events responsible for these changes is called the "recovery" cycle, because of the fact that the system recovers from the sudden development of stratified conditions caused by freshwater discharge. The cycle can be divided into several characteristic phases, which are discussed below.

The onset of winter rains produces such great changes in the horizontal and vertical distribution of temperature, chlorinity, oxygen saturation, and nutrient salts that these constituents become valuable identifying properties in following the subsequent recovery cycle. Many of the changes in these constituents were discussed in some detail earlier; nevertheless it will be necessary to refer to them again, so as to give as complete a picture as possible of the recovery cycle.

All of the theories developed during these investigations have been based primarily on hydrological data, and other analytical techniques are considered as supplementary. For example, no analysis has been attempted of tidal records obtained within the basin; the variations in water level shown by these records have simply been used to assist in explaining the changes in the distribution of hydrological properties. The use of the Pritchard drag technique was designed to elucidate certain hydrological changes occurring in the vicinity of the sill under stratified conditions; because of practical difficulties it was not possible to obtain quantitative volumes with these instruments (Section II(*b*)).

(1) *Reduction in the Intensity of Freshwater Discharge.*—Whereas the intensity of freshwater discharge reaches a maximum at some period during the winter and then begins to fall off, there is a continuous tidal influence from the seaward end of the system. Once the depth of the surface layer has decreased, marine water is free to enter the sill region and ultimately to penetrate into the subsurface waters of the basin.

(2) *Formation of "Sill" Water.*—The interaction between the surface layer and incoming marine water occurs in the sill region; the resultant "sill" water possesses properties which are intermediate between those of the two components. For this reason it moves upstream at some intermediate depth which represents a suitable density level, and does not immediately spill over the sill into the bottom waters of the lower basin. In 1953 the movement of sill water was traced as far upstream as station 4; apparently its identity was retained by the maintenance of a satisfactory balance between the marine and freshwater components.

Figure 31*A* shows several stages in the movement of this sill water past station 3*a*. Before the sill water appeared, the distribution of oxygen saturation in the subsurface waters was allied closely to that of chlorinity on July 17 (cf. Fig. 30*A*), but as the sill water moved upstream this relationship was destroyed. By July 22 the values of oxygen saturation had risen sharply at intermediate depths below the halocline, although no significant chlorinity changes were observed. The desaturated basin water was now confined to the bottom zone (cf. Fig. 30*B*).

The distribution of nitrates and phosphates at station 3*a* has already been referred to in the discussion of nutrient cycles (Figs. 21 and 27); it supports the theory that the initial movement upstream of marine elements, characterized by low nutrient levels, occurred at intermediate depths. An examination of the temperature observations at station 3*a* (Fig. 31*A*) also lends support to this theory in three ways: (i) The depth of the cold surface layer progressively decreased; (ii) below 12 m temperatures remained constant; (iii) there was a significant distortion of the temperature gradient at intermediate depths on July 22. This distortion was no doubt caused by the appearance of a wedge of sill water of uniform temperature (about 16·5°C).

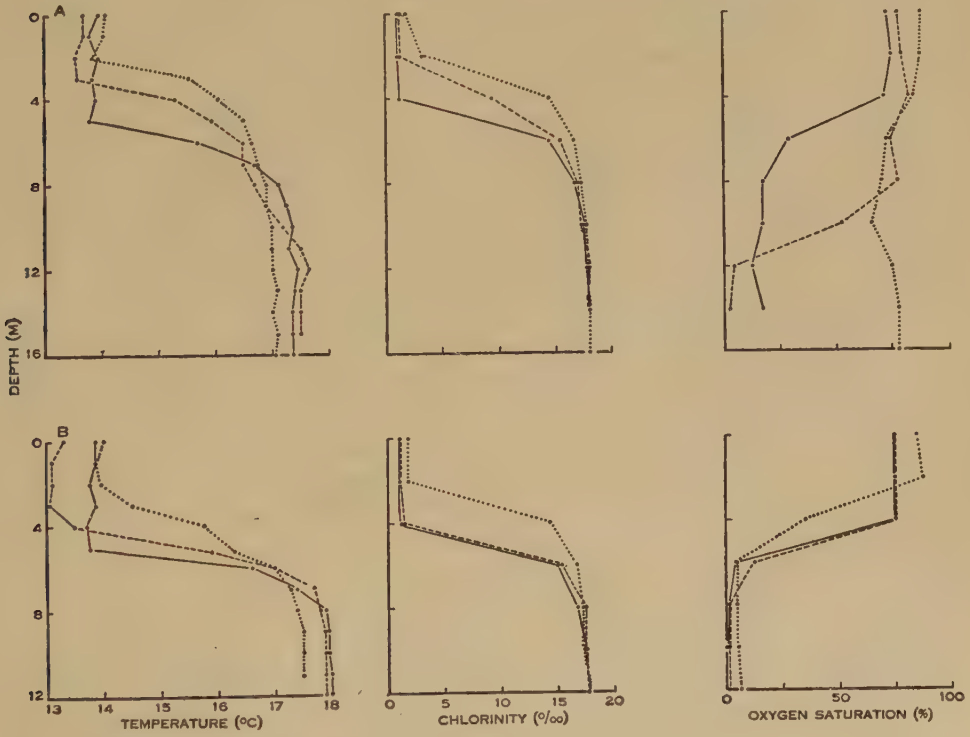

Fig. 31.—Depth profiles of temperature, chlorinity, and oxygen saturation. *A*, at Swan River station No. 3*a*; *B*, at Swan River station No. 5. —•— 17.vii.1953; --•-- 22.vii.1953; •••••• 30.vii.1953.

During this period the effect of marine penetration was not felt in the subsurface waters of the upper basin. The only significant features of the profiles at station 5 (Fig. 31*B*) was a gradual reduction in the depth of the surface layer, which, however, was not so pronounced as it was at Station 3*a*. The initial penetration of marine water tilted the boundary between the surface water and the deoxygenated basin water, as well as elevating it towards the surface (cf. Fig. 30*B*). In the upper basin the region through which this elevation occurred was occupied by the subsurface water, thus compensating for the entry of marine water at the lower end of the basin.

The theory of sill water formation was not formulated until the end of July 1953; hitherto its existence had not been suspected, and it had been assumed that the cascading of marine water into the lower basin bottom waters would occur immediately the depth of the discharge layer over the sill fell below a critical value (Rochford 1951). That such a cascading does occur was established later; in the meantime the results of further studies on sill water formation are presented now.

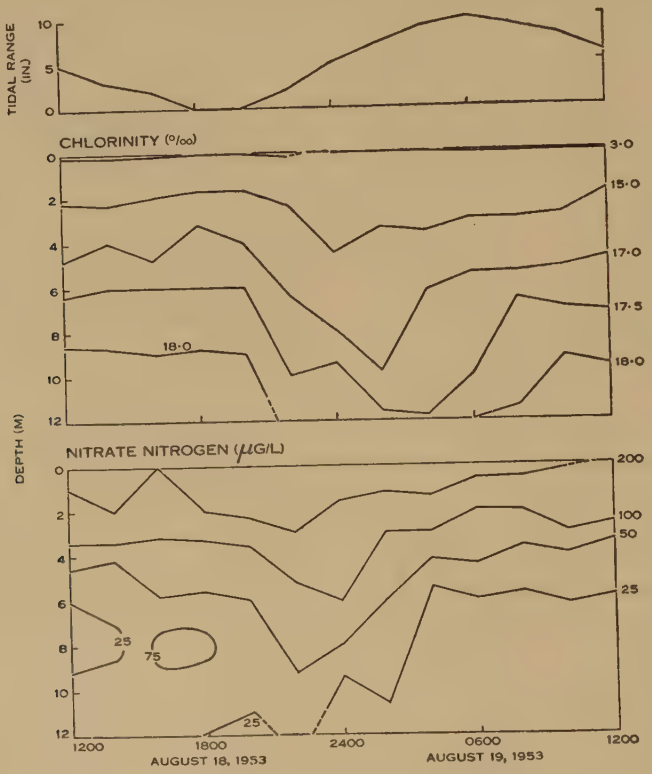

Fig. 32.—Profiles of chlorinity and nitrate nitrogen, with tidal range, at Swan River station No. 3, 18-19.viii.1953.

The first attempt to examine this problem was made about the middle of August 1953. The observation vessel was anchored in the channel about a quarter of a mile above station 3, the depth here being 12 m as against 9 m at the usual sampling point. A vertical sampling profile (at 2-m intervals from surface to bottom) was made every 2 hr over a 24-hr period; simultaneous observations were made on water level by means of a tide stick attached to a nearby jetty.

Figure 32 shows the tidal range and the isochlors plotted along the time scale. It is immediately obvious that the depth of the freshwater layer never exceeded 2 m; in fact there was virtually no change in surface chlorinity values over the period. Notwithstanding the shallow surface layer the results indicated that sill water was produced during the flood cycle.

Once the water level commenced to rise there was a pronounced drop in chlorinity at subsurface levels; in fact the 18‰ isoline was absent during most of the flood phase. The flooding water mass apparently consisted of a front of sill water, the amount of which depended more on the freshwater component than the marine one, since the former was more variable. The movement of this front past the sampling point actually caused a temporary dilution of the subsurface waters.

As the water level continued to rise the initial fall in chlorinity of the subsurface waters was followed by an appreciable rise. This is not unexpected, since the intensification of the flood cycle simply meant that the marine component of the sill water was now increasing at the expense of the freshwater component. A rise in subsurface chlorinity values must inevitably accompany the movement of this sill water into the basin.

Determinations of nitrate nitrogen were made on all samples collected during this survey. Although the peak of discharge values had been reached a month or so previously, the surface layer still contained sufficiently high concentrations of this component to introduce it into the sill water. The profile of nitrate shown in Figure 32 is complicated slightly by the fact that when the survey commenced, the bottom waters at the station were somewhat deoxygenated and their nutrient concentrations were rather high. This is rather surprising in view of the absence of any deoxygenation in the lower basin a few days later (cf. Fig. 36). However, the high nitrate values did not persist throughout the ebb phase, so that when the flood phase commenced the subsurface values were low. The initial penetration of sill water brought with it appreciable quantities of nitrate, which was presumably derived from the discharging surface layer. However, as the marine component of the sill water increased, the concentration of nitrate was rapidly reduced, so that at the end of the survey the subsurface waters contained only very small amounts of nitrate.

The hypothesis of sill water formation suggests that under the conditions prevailing at the time of the survey a complete flood cycle produced a slight horizontal chlorinity gradient in the subsurface waters of the lower basin. In other words the drop in subsurface chlorinity occurring at the beginning of each flood cycle was a transitory process, and the sill water thus formed would be unable to retain its identity within the basin. A general survey of the whole basin about this time showed that such was the case (Fig. 36); the subsurface waters of the lower basin had been completely ventilated by marine water, and no trace of sill water remained at subsurface levels.

It must be remembered, however, that the depth of the discharge layer, although not exactly known, never exceeded 2 m, whereas at an earlier stage of run-off the depth had been at least 4 m. In such a case the freshwater component of the sill water would be appreciably greater than it was during the present survey. The high velocities associated with such a deep freshwater layer would create more turbulent conditions in the sill region, with a subsequent increase in sill water formation. During the latter part of July 1953 this process must have been far greater than it was at the time of the 24-hr survey in mid August.

In 1954 it was hoped that a more or less continuous production of sill water could be observed by carrying out a similar survey at the height of discharge intensity, when the surface layer would be much deeper than 2 m. Unfortunately such a condition did not develop during this winter, because of the low rainfall. Nevertheless, several surveys carried out in this region in 1954 yielded some interesting results.

The first survey was carried out in July, following an elevation of the water level of the basin similar to that shown in Figure 4*B*. This elevation of water level was associated with a considerable penetration of marine water into the lower basin, under the influence of a cyclonic depression offshore. The subsequent discharge accounts for the gradual decrease in chlorinity throughout the ebb phase (Fig. 33); the fact that no clearly defined surface layer was present contrasts sharply with conditions prevailing in August 1953. Nevertheless, the commencement of the flood cycle was once again associated with a fall in subsurface chlorinity values, and with a subsequent rise as the marine component of the incoming water mass increased at the expense of the freshwater component.

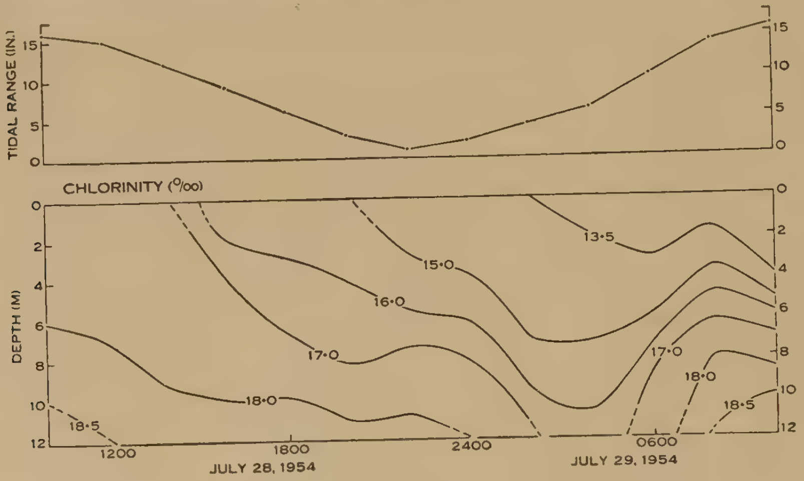

Fig. 33.—Chlorinity profiles and tidal range at Swan River station No. 3, 28-29.vii.1954.

In August 1954 the Pritchard drag technique was used during a similar survey at station 3, in conjunction with the hydrological observations. This survey was carried out during a period of semi-diurnal tides of small amplitude, so that two complete flood cycles were examined instead of one. The profiles of chlorinity and current velocity are shown in Figure 34 together with the tidal range. There is a gap in these graphs between 5 and 8 p.m. on August 16 because no observations were made during this period. Unfavourable weather conditions which developed on August 17 made it impossible to continue current velocity measurements after 10 a.m.

In the early part of this survey the final stage of a flood cycle (F_1) was associated with increasing chlorinity as marine water entered the basin. It is interesting to note that the subsequent ebb cycle (E_1) produced no immediate fall in chlorinity, even though the entire column was moving downstream at 5 p.m. on August 16. The same effect was observed during ebb cycle E_2, although here the magnitude of discharge was greatly reduced by the smaller amplitude.

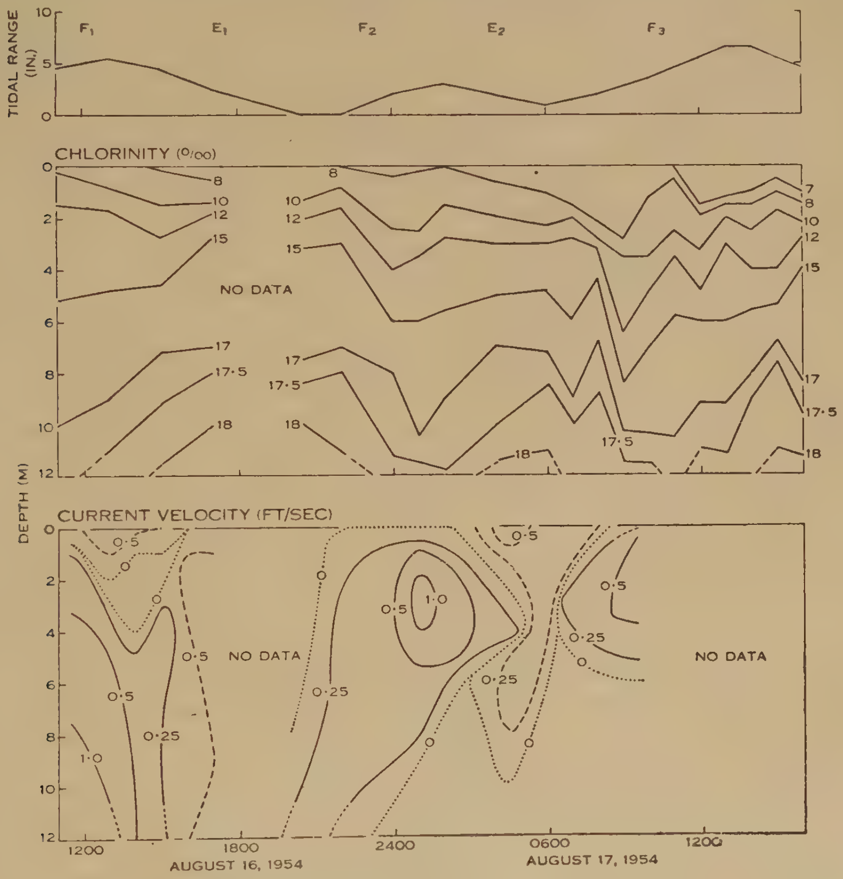

Fig. 34.—Profiles of chlorinity and current velocity, with tidal ranges, at Swan River station No. 3, 16-17.viii.1954. —•— Flood velocities; --•-- ebb velocities.

Another interesting feature of this survey was the different behaviour of isochlors at intermediate depths during the two flood cycles F_2 and F_3. F_2 was preceded by an ebb cycle (E_1) large compared with that (E_2) preceding F_3. As a result a greater amount of sill water was present in the tidal front of F_2, so that following on the initial fall in chlorinity the intermediate waters were maintained at a reasonably constant chlorinity. Because of the reduced magnitude of E_2 the sill water entering on F_3 contained a higher proportion of the marine component, and therefore caused a rapid rise in chlorinity at intermediate depths following the initial fall.

During the course of this survey there was a progressive fall in surface chlorinity values from 10‰ at the beginning to below 7‰ at the end. In this respect conditions differed from those prevailing during August 1953, when a clearly defined freshwater layer persisted throughout the 24-hr period.

A sampling point was chosen at the upstream end of the sill, and a similar survey, combining hydrological observations with current velocity measurements, was made at this point early in September 1954. The profiles of chlorinity, current velocity, and oxygen tension are shown in Figure 35, together with the tidal range.

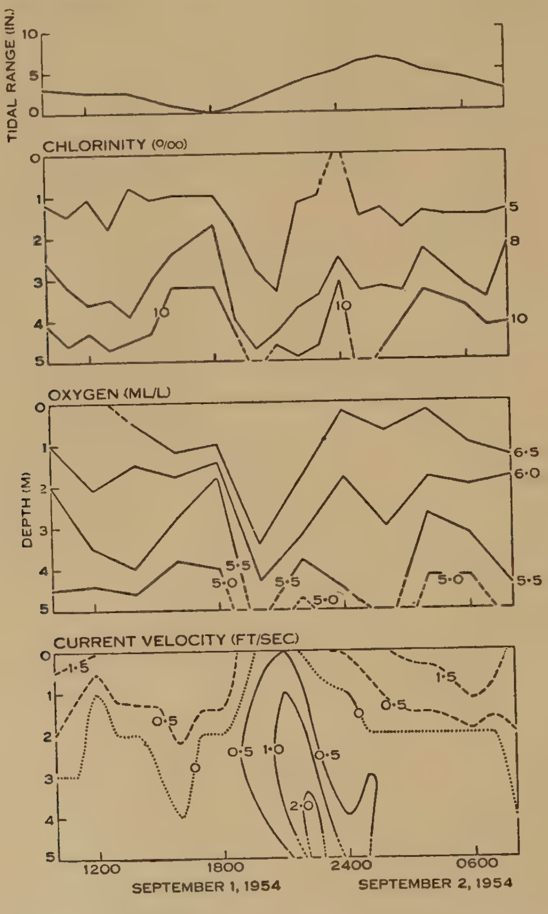

Fig. 35.—Profiles of chlorinity, dissolved oxygen, and current velocity, with tidal range, at the upper end of the sill, between Swan River stations Nos. 2 and 3, 1-2.ix.1954. —•— Flood velocities; --•-- ebb velocities.

The seaward movement of the surface water was confined to the uppermost 2 m, whereas the flood cycle initiated an upstream movement of the whole column. Under these conditions the familiar fall and rise in subsurface chlorinity was once again observed.

The information obtained from each of the above-mentioned surveys has been used to explain satisfactorily the presence of the wedge-shaped water mass which was observed in the subsurface waters of the basin during July 1953. The marine component was responsible for the high oxygen and low nutrient concentrations of this water mass, while the freshwater component adjusted the chlorinity, and hence the density, to values less than those of the basin bottom waters; in this way the sill water mass moved upstream at intermediate depths instead of spilling into the basin bottom waters.

The assumption has been made here that a freshwater layer of sufficient depth will maintain the generation of sill water at a more or less continuous rate. It is unfortunate that since this assumption was first made no suitable conditions of freshwater discharge have developed in the system. It is hoped that such a project can be undertaken when favourable conditions arise.

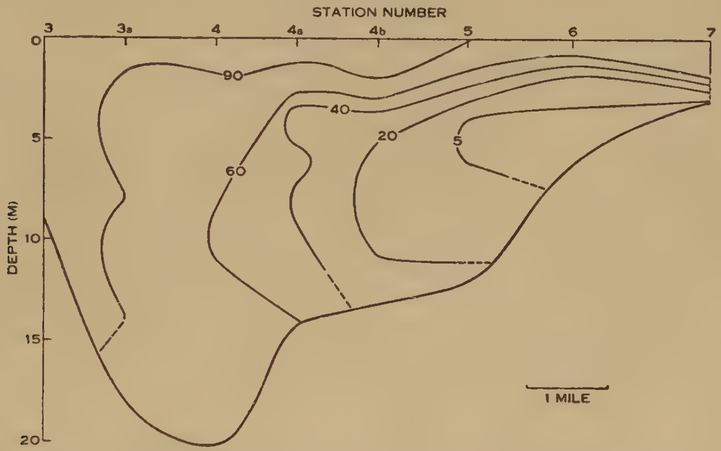

Fig. 36.—Longitudinal profile of oxygen saturation within the Swan River basin, 13.viii.1953. Numbers on curves are percentage oxygen saturation values.

Because of the practical difficulties associated with the operation of more than one sampling point during the hours of darkness, no cross-sectional sampling has been attempted in these studies of sill-water formation. In view of the possibility of asymmetrical flow such a procedure might prove invaluable, but for the present it must await future developments in instrumentation and methodology.

(3) *Cascading of Marine Water into the Basin.*—Since the composition of sill water is controlled by two variable factors it cannot be maintained unless the proportions of these factors remain reasonably constant. It is therefore inevitable that as the depth of the surface layer is reduced the marine component in the sill water should begin to predominate. The subsequent increase in the chlorinity of the sill water enables it to enter the bottom waters of the lower basin, and a cascading takes place. This effect was observed during the early part of August 1953, by which time the subsurface basin waters as far upstream as station 4 had been ventilated by the incoming marine water (Fig. 36). The associated fall in temperature is readily explained by the fact that the basin water had been isolated at a relatively high temperature by the early onset of stratification in this particular year (Section VI(*a*)). The marine water entering the basin in August was appreciably colder,

and therefore denser, than this original basin water, although the chlorinity changes during this period were not great.

Up to this stage of the recovery cycle the entry of marine elements occurs in two stages: the initial wedge penetration of sill water, and the subsequent cascading of a denser marine water into the deeper waters of the basin. Beyond station 4 the depth of the basin gradually decreases, and the effectiveness of the cascading process as a mixing mechanism must inevitably be reduced.

Some indication of the manner in which incoming marine elements are distributed at this stage of the cycle is given in Figure 36, which shows the longitudinal profile of oxygen saturation on August 13, 1953.

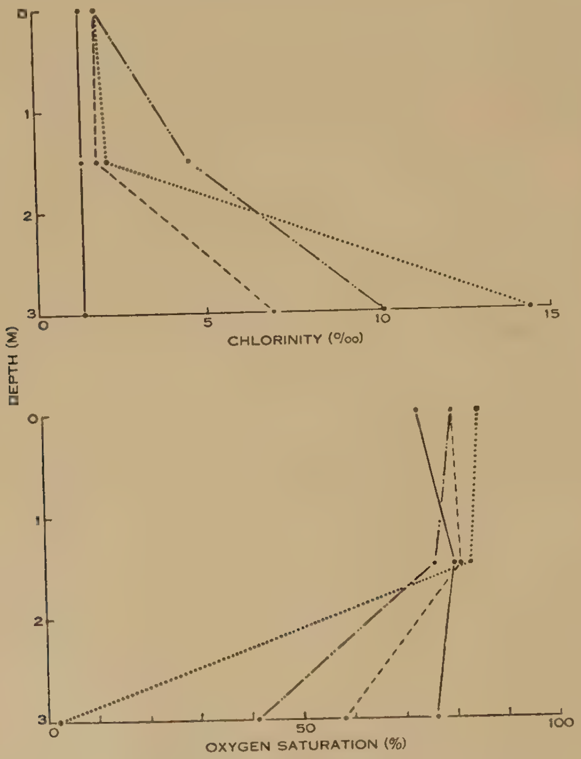

Fig. 37.—Depth profiles of chlorinity and oxygen saturation at Swan River station No. 7. —•— 22.vii.1953; --•-- 30.vii.1953; —•—••— 5.viii.1953; •••••• 13.viii.1953.

Whereas the waters below the halocline at the lower end of the basin had been replenished, the zone of oxygen desaturation was still apparent further upstream as an intermediate layer. The pronounced rise in the oxygen content of the bottom waters between stations 4 and 5 suggests that this region was being affected by the upstream movement of marine elements as a bottom wedge, a theory which is supported by the associated fall in nutrient concentrations (Section VII).

It is important also to realize that by this time the original desaturated basin water had penetrated at least as far upstream as station 7, where it was now observed as a thin bottom layer (Fig. 37). This degree of stratification within a few metres, and the nature of its development, typify the poorly developed vertical turbulence in the upper basin region. Between July 22 and August 13 the depth of the surface discharge layer at station 7 decreased sufficiently to allow the passage of desaturated basin water past this point. In this way a pronounced halocline was established without any significant change in surface chlorinity values over the period.

The cycle thus advances a step further: the entry of marine elements and the subsequent movement upstream of stagnant basin water are compensated by a marked decrease in the depth of the freshwater layer. The sharp halocline which characterized the height of the discharge phase has been destroyed by the increased mixing between surface and subsurface waters. At this stage of the cycle surface temperatures begin to rise (Section VI(*a*)) and the vernal nutrient utilization becomes evident (Section VII).

(4) *Hydrological Significance of Mean Water Level Changes within the Basin.*— During the spring period the distribution of hydrological properties within the basin is controlled to a large degree by variations in the mean water level of the basin. It is important to realize that these variations are associated with changing barometric conditions, and cannot be caused by variations in freshwater discharge, as rainfall during this period is slight (cf. Fig. 3).

Under conditions of falling water levels the zone of oxygen desaturation is shifted downstream at subsurface levels. The subsequent elevation of water level is caused by the entry of marine elements owing to a change in barometric conditions, which develops a pressure head at the marine end of the system. The stagnant zone is destroyed at its seaward end and at the same time is shifted further upstream. The marine pressure is sometimes sufficient to elevate the stagnant zone towards the surface; the increased mixing thus induced accounts for the increase in surface chlorinity values, and ultimately decreases the size of the stagnant zone. Eventually this zone becomes isolated in the bottom waters on the upper slope of the basin, in the region of station 5 (cf. Fig. 30*D*). The final step in the cycle is the destruction of this isolated pocket of desaturated water, so that homogeneous conditions which characterize the summer-autumn period are restored.

Observations made during the first half of September 1953 show the changes which occurred in the basin during a period when the mean water level first fell and then rose to about its original height. Records taken from the tide recorder operated by the Western Australian Department of Harbours and Rivers at a point between stations 7 and 8 show clearly that there was an appreciable fall in water level between September 2 and 9, followed by a rise during the ensuing week. Such a cycle of events is consistent with the hydrological observations showing that the stagnant zone had shifted downstream, so that it was detected at intermediate levels at station 3*a* on September 9 (Fig. 38). The subsequent entry of marine elements was responsible for the increased oxygen values observed at this station on September 16, and for the fact that nitrate had disappeared completely from the zone where maximum concentration had been observed a week before.

None of these changes would be suspected from an examination of the chlorinity distribution on the three dates. The fall in surface values, and their subsequent increase, were so slight as to be insignificant, particularly at depths below 4 m. However, when they are considered in association with the observations on other properties, they support the theory that the subsurface waters had moved downstream under the influence of falling water levels.

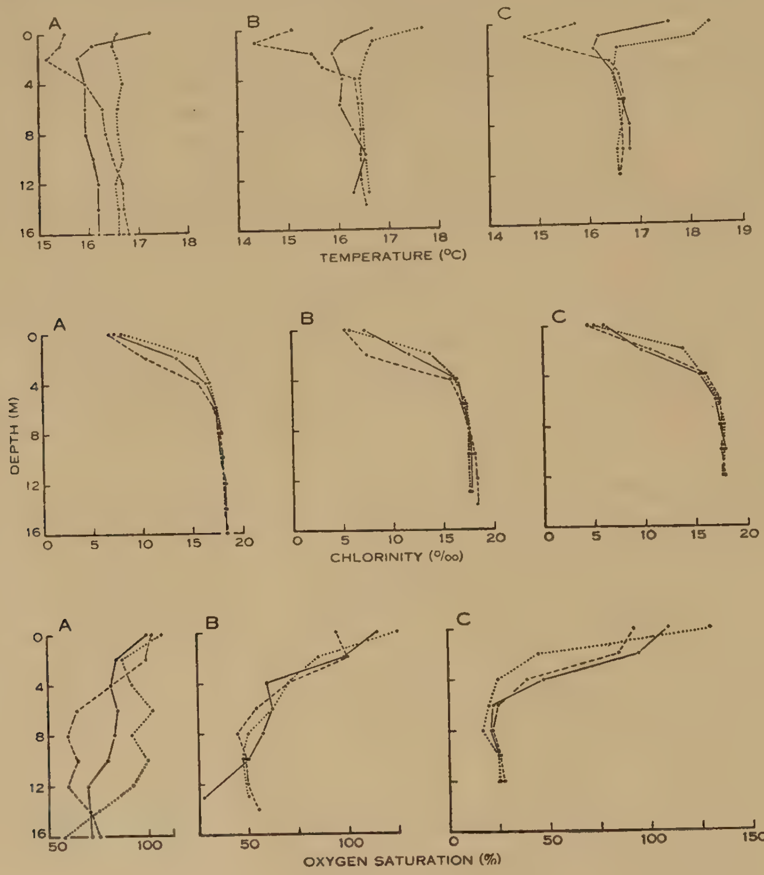

Fig. 38.—Depth profiles of temperature, chlorinity, and oxygen saturation. *A*, at Swan River station No. 3*a*; *B*, at station 4*a*; *C*, at station 5. — • — 2.ix.1953; -- • -- 9.ix.1953; •••••• 16.ix.1953.

At the upper end of the basin, conditions remained unchanged during this period, indicating that the penetration of marine elements was not sufficient to affect the region. The steady decrease in nutrient levels observed during this period has already been referred to (Section VII).

Between September 16 and 24 the changes in water level were so slight that no great changes in hydrological conditions could be expected. Figure 39 shows that none occurred; subsequently, however, a rise in water level was accompanied by a pronounced increase in chlorinity, particularly in the lower basin. These changes were associated with rising temperatures in the subsurface waters as sea-water entered from the marine end. In the central region (Fig. 39*B*) a pronounced elevation of the desaturated zone had occurred, and it was apparent that water of high chlorinity and low oxygen tension was being transported into the surface layers. At the same time the observed rise in the chlorinity of the bottom waters, although slight, was significant enough to show that penetration of marine elements was occurring at this level. This penetration explains the increasing oxygen tension in the bottom waters as far upstream as station 5 (Fig. 39*C*).

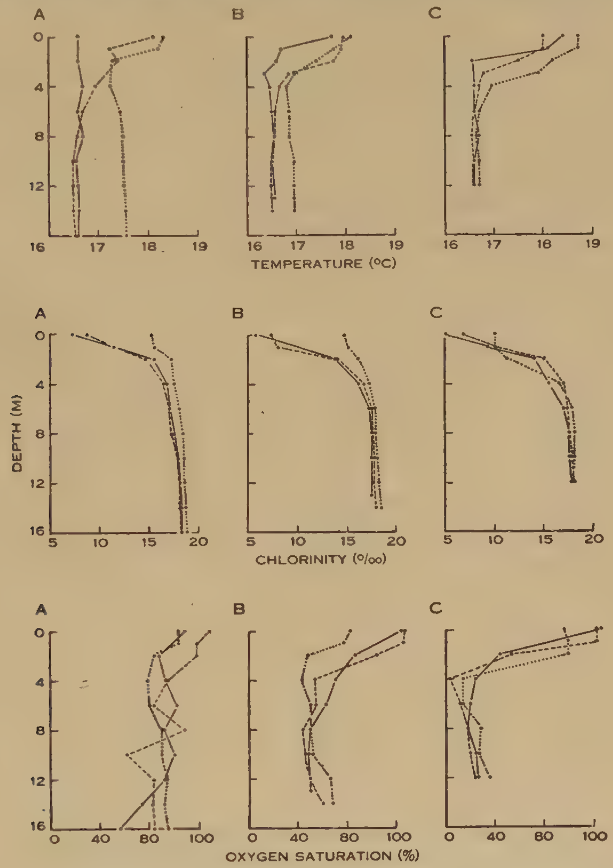

Fig. 39.—Depth profiles of temperature, chlorinity, and oxygen saturation. *A*, at Swan River station 3*a*; *B*, at station 4*a*; *C*, at station 5. —•— 16.ix.1953; --•-- 24.ix.1953; •••••• 30.ix.1953.

These results suggest that marine elements are continually being supplied to the basin waters, either by invasion through the bottom zone or by some mechanism which accounts for the increasing chlorinity of the surface waters. On the other hand the depression of surface chlorinity values, which occurs when the water level falls, can extend to the subsurface waters, so that there is a significant drop in the chlorinity values throughout the entire water column. In this way there is an actual loss of marine elements from the system, and it would appear that the recovery cycle is temporarily delayed.

This sequence of events was actually observed during the first half of October 1953. An examination of tidal records for this period shows that a substantial drop in water level occurred during the first few days of the month, followed by a period of semi-diurnal tides of small magnitude, during which the water level remained low (cf. Fig. 4*C*). The result was a large-scale displacement seaward of the basin waters, which was not confined to the surface zone (Fig. 40). There was a significant decrease in the chlorinity of the whole water column throughout the basin, associated with the disappearance of the intermediate stagnant zone which had been observed at the end of September.

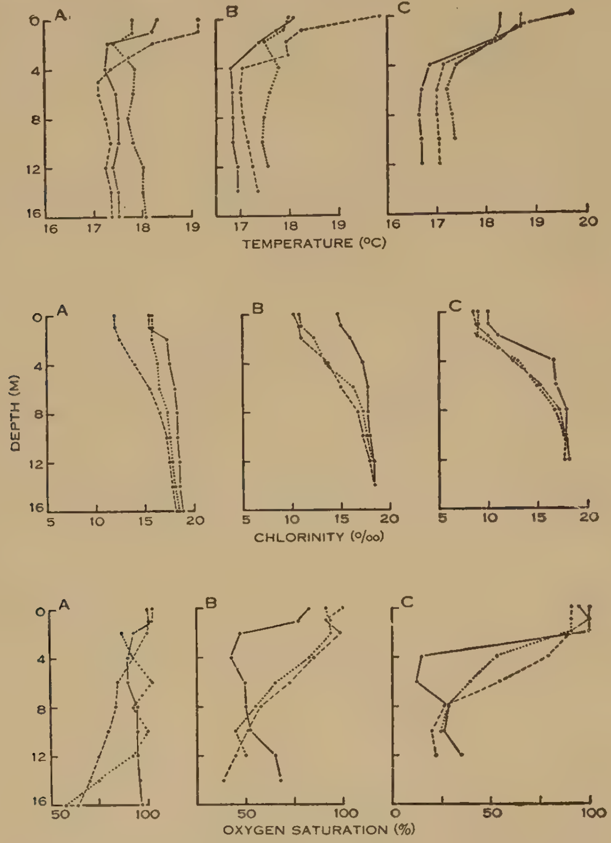

Fig. 40.—Depth profiles of temperature, chlorinity, and oxygen saturation. *A*, at Swan River station 3*a*; *B*, at station 4*a*; *C*, at station 5. —•— 30.ix.1953; --•-- 8.x.1953; •••••• 16.x.1953.

This process of rearrangement of oxygen distribution is of considerable importance; a sharp fall in water level apparently achieved in a short time what the entry of marine elements had only partly accomplished up to this stage of the cycle.

The temperature distribution within the surface layers during this period is also of particular interest. The marked fall in chlorinity values during the first week of October was accompanied by the appearance of a pronounced thermocline, which was no doubt caused by the movement into the surface waters of the basin of high-temperature, low-salinity water from the region further upstream. The subsequent entry of marine water was brought about by an increase in tidal amplitude which affected only the lower basin region, and did not produce a significant elevation of water level. Despite this fact, the thermocline disappeared at all the basin stations, including those at the upper end, which showed no significant changes in chlorinity. The establishment of thermal homogeneity observed on October 16 is attributed to the mechanism referred to previously, which accounted for the transport of subsurface water towards the surface.

This proposed transport should also cause an increase in the chlorinity of the surface waters, and the fact that such an increase was not observed on October 16 could be advanced as an argument against the explanation of the temperature changes. However, it is conceivable that the profiles observed on October 8 represented the end-point of the temperature rise at the surface, but not the end-point of the chlorinity drop. In other words, the chlorinity of the surface waters may have fallen well below that observed on October 8, without much variation in temperature.

Several important facts arising from the examination of the data obtained during the spring of 1953 may be summarized as follows.

(i) The distribution of properties within the basin is affected by the variations which occur in mean water level.

(ii) A rise in water level can cause the destruction of the stagnant zone at its seaward end, and at the same time marine elements penetrate into the bottom waters of the upper basin.

(iii) The stagnant zone shifts to and fro within the basin, occasionally being elevated towards the surface where it mixes with the overlying waters.

(iv) A sharp fall in water level can disrupt the stagnant zone so that it no longer persists at intermediate depths.

(v) Some mechanism exists which accounts for the mixing between surface and subsurface waters.

(5) *Internal Wave Formation.*—A hypothesis which postulates the presence of internal waves within the basin has been developed as a result of continuous observations at selected stations as well as certain phenomena observed during routine surveys. The rapid disappearance of the thermocline during the first half of October 1953 (Fig. 40) and the change which occurred in surface oxygen values at the end of September 1953 (Fig. 39) suggested that considerable mixing was occurring between surface and subsurface waters on these two occasions. In each case a pronounced gradient of properties disappeared within a week of its development. The nature

of its disappearance indicated that subsurface water was being transported across the existing chlorinity boundary, so as to produce homogeneous conditions in the surface layers.

It is possible that the commencement of the flood cycle generates an internal wave at the seaward end of the system, and that this wave travels through the basin at intermediate depths. This theory has been tested by observing the changes occurring in the vertical distribution of properties at selected basin stations during at least one tidal cycle.

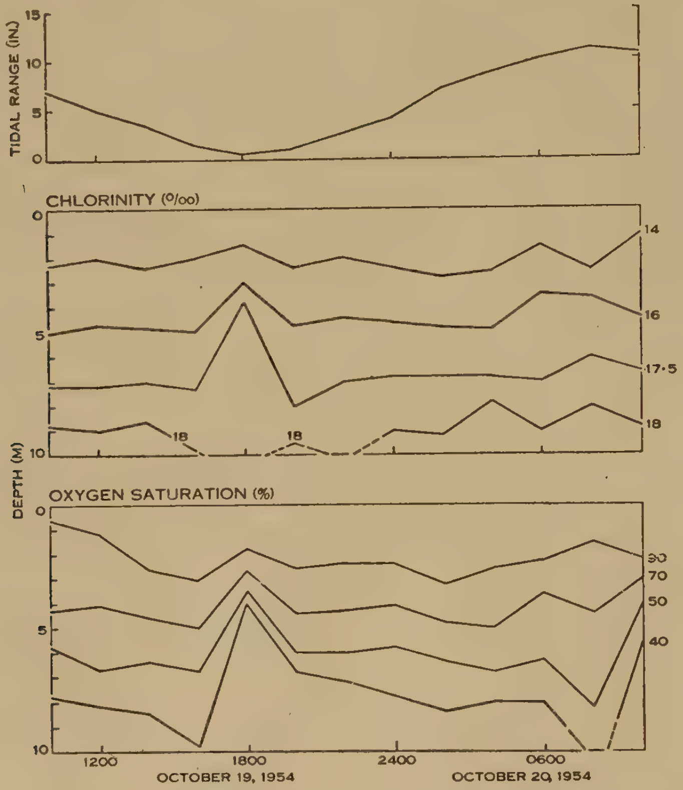

Fig. 41.—Profiles of chlorinity and oxygen saturation, with tidal range, at Swan River station 5, 19-20.x.1954.

Figure 41 shows the results of such a survey at station 5. Although stratification was not intense at the time of this survey the bottom waters nevertheless showed an appreciable oxygen depletion. Throughout the period of observation the vertical range of chlorinity and oxygen saturation remained constant, but a pronounced rise and fall of the isolines occurred at subsurface levels during the period of minimum water level. Allowing for a tidal lag between this point and Fremantle Harbour of over an hour, it is conceivable that the observed oscillations were caused by an internal wave generated at the lower end of the basin at the commencement of the flood phase.

A number of surveys were carried out at station 6 to examine the changes occurring in the subsurface waters. The first of these, extending over one diurnal tidal cycle, was carried out in October 1953; the profiles of chlorinity and oxygen saturation are shown in Figure 42. The outstanding feature of this survey was the transitory appearance of high-chlorinity water, associated in all cases with substantial decreases in oxygen saturation, at various stages of the tidal cycle. Although the initial appearance of this water was not detected it is apparent that it was more intense than the two following waves. The cessation of the ebb phase on October 22 was accompanied by the reappearance of high-chlorinity water as the subsurface isolines were substantially elevated.

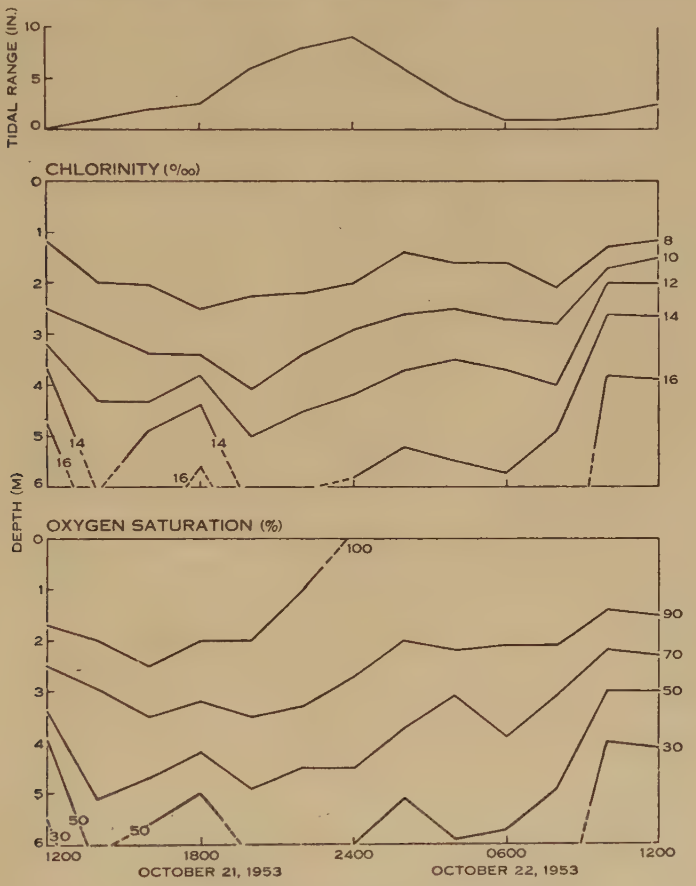

Fig. 42.—Profiles of chlorinity and oxygen saturation, with tidal range, at Swan River station 6, 21-22.x.1953.

There are two differences between the results of this survey and that carried out at station 5, but both can be explained satisfactorily. Firstly, more than one oscillation was observed at station 6, whereas only a single oscillation occurred at station 5. This effect was probably due to the reflection of the initial wave. It must be remembered that the depth at station 5 is twice that at station 6, which is surrounded by shallow banks on the upper slope of the basin; it is here that complications of the initial wave could easily occur.

The second difference is that the vertical range of chlorinity and oxygen saturation did not remain nearly so constant at station 6 as station 5. This means that "basin" water (that is, water of high chlorinity and low oxygen saturation) actually moved to and fro past station 6. The slight horizontal velocities associated with the passage of the internal waves could account for this effect at station 6, whereas in the open channel at station 5 no change in the vertical range of hydrological properties could be expected, because of the similarity of these properties in the subsurface waters above and below this sampling point.

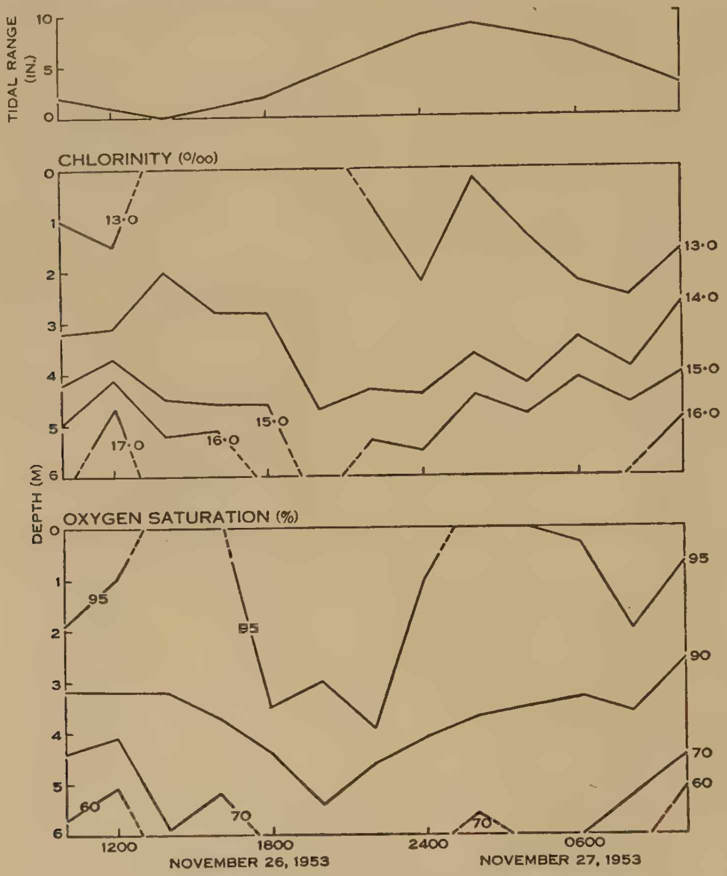

Fig. 43.—Profiles of chlorinity and oxygen saturation, with tidal range, at Swan River station 6, 26-27.xi.1953.

Surveys carried out at station 6 under various weather conditions during the late spring period showed that the formation of these internal waves was not constant. The chlorinity and oxygen saturation profiles of one such survey are shown in Figure 43; it is apparent that the initial wave, observed at the end of the ebb phase on November 26, was not reflected during the ensuing flood phase; indeed its magnitude was considerably smaller than that observed in the previous survey at this station. No significant elevation of the subsurface isolines was observed until the end of the ebb phase on the following day; this effect is presumed to be caused by the generation of a new wave at the lower end of the system.

Since the tidal range was the same in each case (9 in.) it is difficult to understand why the wave generated in the November survey was so weak compared with that observed in the previous month. It may be significant that during the November survey an easterly land breeze predominated, whereas the south-westerly sea breeze had developed strongly during the flood phase of the October survey. This wind may possibly reinforce the tidal effect which is presumed to generate the internal wave, whereas an offshore wind would react against it.

There is insufficient evidence available at present to justify such an assumption, that both the direction and intensity of local winds play some part in the development of internal waves; indeed it would be unwise to make this assumption without first undertaking further investigations designed to elucidate the problem. Some system of simultaneous sampling at more than one station within the basin must be devised if a more critical examination is to be made of the characteristics of these waves.

IX. Discussion

As a result of the investigations carried out on the Swan River the fundamental differences between this system and those of eastern Australia are now more clearly understood. The most important of these is tidal amplitude, which is considerably less in south-western Australia than it is along the east coast. A diurnal tidal oscillation of about 1 ft in the Swan River contrasts sharply with the semi-diurnal oscillation of 5 ft observed in the Hawkesbury River. Any changes in the mean water level of the latter system due to local barometric effects are completely masked by these comparatively large lunar tides; on the other hand it has been shown that the magnitude of such changes in the Swan River can actually exceed the diurnal tidal range, so that weather conditions play a very important part in the circulation of this system.

In some years the recovery cycle was not completed before the end of summer, although the intensity of stratification in the previous winter discharge period was not abnormal. It is highly probable that this state of affairs was caused by a particular sequence of weather conditions during the late spring period, which delayed the entry of marine water into the basin and so extended the recovery cycle beyond its normal time range.

Because of the great differences in vertical mixing, a system such as the Hawkesbury River recovers more rapidly from freshwater invasion than a system such as the Swan River. The former can rapidly establish an equilibrium salt balance, whereas in the latter there are rather drastic and prolonged changes in hydrological properties. The recovery of the Hawkesbury River is controlled largely by tidal mixing, whereas that of the Swan River is more dependent on the peculiar rainfall regime, which usually ensures a rapid reduction in the contribution of fresh water in spring, and on barometric changes which may occur during this period.

The development of an intense chlorinity stratification under the influence of freshwater discharge is common to all the estuarine systems of south-western Australia, where the effective rainfall is confined to the southern winter months. In most of these systems there is somewhere a shallow sill separating a deep basin from either the sea or an inlet of the sea. Such regions include the Murray River in the Peel-Harvey Inlet, the Collie River in Leschenault Inlet, the Blackwood River in Hardy Inlet, the Frankland River in Nornalup Inlet (as well as the inlet itself), the Denmark River in Wilson's Inlet, and the King and Kalgan Rivers, which enter King George Sound.

No intensive study has been made of any of these systems; they were sampled during drought and flood conditions in the early stages of the Swan River investigations. They are subject to the same marine domination during the summer, and the same intense stratification under the influence of winter freshwater discharge. There can be little doubt that in each system the geographical relationship between the shallow sill and the deeper basin further upstream is important in the recovery cycle between winter and summer conditions.

This relationship has been established in the Swan River; in the lower basin the cascading of marine water observed in the winter of 1953 is possible because of the depth contour of the basin, and the associated mixing processes are responsible for the fact that the oxygen desaturation and nutrient production which occur in the subsurface waters in winter do not persist for any appreciable time. On the other hand the depth of the basin channel decreases above station 4, so that the subsurface waters of this region remain in a state of oxygen depletion for prolonged periods during the recovery cycle.

Any further study of the circulation within other estuarine systems of south-western Australia should take into account the depth contour of any basin regions. A prior knowledge of this contour could assist greatly in predicting the nature of the recovery cycle which follows the establishment of winter stratification.

Reference has already been made (Section I) to the difficulties encountered in attempting to classify the Swan River. If the system were subjected to a more or less continuous supply of fresh water it might be possible to differentiate between surface and bottom waters, and to propose a classification based on such a differentiation. But the seasonal range of freshwater contribution is such that the zonal classification of the surface waters ranges from marine domination in the summer to freshwater domination in the winter.

The subsurface waters of the basin do not normally undergo such a transformation, but under stratified conditions they could be called marine-dominated only on the score of chlorinity; other hydrological properties, such as oxygen, hydrogen ion concentration, and nutrient salts, are affected in such a way that they certainly are not characteristic of marine waters.

The term "atidal climatic system" may be an acceptable one with which to classify the Swan River, so long as the following points are remembered:

(i) The word "atidal" is a comparative one only, and does not mean that tidal energy is completely absent. Although this energy is never high it is still an important factor in the establishment of homogeneous conditions in summer, when the climate is dominated by drought conditions.

(ii) The word "climatic" indicates that the supply of fresh water from the headwaters of the system is not maintained above some minimum amount, because of these drought conditions, which are a regular feature of the climate of south-west Australia.

(iii) The whole term implies a seasonal development of stratified conditions, which are persistent enough, in view of the "atidal" nature of the system, to produce drastic changes in the distribution of hydrological properties.

Some of the processes which occur when once the Swan River becomes dominated by winter rains are now clearly understood; however, any further investigations in the basin region should be designed to elucidate several problems which remain only partly solved.

The contribution of nutrient material made by the discharge waters requires further examination. Considerable quantities must be lost to the sea once there is no horizontal density gradient through the surface waters, and sufficient pressure from the head of the system to force fresh water out to sea. However, observations in the winter of 1953 suggest that the surface waters supply phosphate to the subsurface zone, and it may be that nitrogen is also contributed in appreciable amounts. This latter possibility could be examined by observing the role of ammonia, as well as that of nitrate.

The contribution of nutrient material to the system by the bottom mud would be a study in itself, but it does offer excellent opportunities in the Swan River. During the course of these investigations the phosphate profile has often suggested that the bottom muds were contributing this nutrient to the overlying water; nitrate distribution has occasionally suggested a similar process.

Little is known of the short-term oscillations which occur under stratified conditions, and there are also the variations in water level of the basin which are long-term by comparison. The presence of internal waves, and their effectiveness in the process of vertical mixing, must be tested by simultaneous sampling at two or more points within the stratified basin.

Because the present work was designed in its later stages to study some of the circulatory processes of the Swan River, the knowledge gained will no doubt be of value in any pollution studies which may be carried out in the future. The fate of industrial effluents would no doubt differ greatly in the summer period, when the flow of surface water is extremely sluggish, from that in the winter, when the discharging fresh water moves through the system with a greater velocity. In any case the "pollution" induced by natural causes during the winter-spring period must not be overlooked, in view of its magnitude. Under average rainfall conditions this phenomenon regularly reduces a considerable proportion of the basin's total volume to an almost anaerobic state. The fact that these conditions persist in the upper basin for weeks and sometimes months means that considerable mortality of aerobic organisms must occur in this region.

The programme of intensive sampling shows also that the stagnant zone does not remain stationary, but moves up and down in both vertical and horizontal directions, so that it must affect different regions within the basin depending on the prevailing conditions. During spring the surface waters, by virtue of the considerable contribution of nutrient material made to them by freshwater discharge, become an ideal medium for the growth of photosynthetic organisms. It is highly probable that such growth would occur even in the absence of industrial effluents. The toxicity of the latter is the real factor which must be supervised and controlled.

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STUDIES ON AUSTRALIAN CUBOMEDUSAE, INCLUDING A NEW GENUS AND SPECIES APPARENTLY HARMFUL TO MAN

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Summary

A series of large Cubomedusae from northern Australian seas—Darwin and north Queensland—has been examined. These are of a single species, described here as *Chironex fleckeri*, gen. nov., sp. nov. Morphological and systematic studies have been made. It is shown that the system of gonads is markedly different from that obtaining in other Cubomedusae, in which the gonads are leaf-like lamellae that arise at the interradial septum and project into the perradial stomach pouches. In *Chironex*, only a narrow ridge is present at the interradial septum in the same situation, at most about 0·4 mm wide, and the gonads are lobulated structures that arise alongside the perradial suspensoria, high in the bell cavity, and project into the bell cavity. This structure is also present in the genus *Chiropsalmus*, but in more primitive form, and in the past has been called the "gastric saccule", of unknown function. It is apparently absent (judging by the literature) in other Cubomedusae. The histology of the gonads and other relevant features in *Chironex fleckeri* are described.

The term "superior gonad" is introduced for what has hitherto been called the "gastric saccule", and the term "lateral gonad" is used for the structure arising at the interradius in the perradial stomach pouches.

The systematics of the Cubomedusae are reviewed in the light of the differences in the gonads. The family Chironecidae, fam. nov., is raised for *Chironex*, gen. nov. The genus *Chiropsoides*, nom. nov., is proposed for *Drepanochirus* Krumbach, 1925 (non Péringuey 1901 preoc.), and hence Chiropsoididae, nom. nov., for the family Drepanochiridae Krumbach, 1925.

The clinical effects of the stingings of Cubomedusae on man are considered briefly, where relevant. It is probable that *Chironex fleckeri* is responsible for severe stingings and deaths of humans in northern Australian waters, but direct proof of this hypothesis is lacking.

I. Introduction

Over a number of years marine stingings of humans, of great severity, have occurred in northern Australian waters. Although these have been responsible for a number of deaths of bathers, the agent or agents responsible for these deaths have not been identified with any certainty, mainly because of the difficulty of capture and preservation of these presumably transparent forms. For various reasons it has been suspected that the agent responsible was most likely to be a large cubomedusan jellyfish, provisionally allotted to the genus *Chiropsalmus* L. Agassiz, 1862. McNeill and Pope (1943*a*, 1943*b*) appear to have been the first to suggest that such Australian stingings were due to a Cubomedusa. Later one of these authors (Pope 1953) published a photograph of a Cubomedusa from Palm Beach, north Queensland, forwarded in 1951 by Dr. H. Flecker to the Australian Museum (the legend to the photograph states "taken . . . in January, 1953") "which we believe to be a juvenile of the species *quadrigatus*" (of the genus *Chiropsalmus*).

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She commented further " . . . it is now reasonably certain that the jellyfish causing the deaths of bathers [in north Queensland] has been . . . found to be a carybdeid medusa, *Chiropsalmus quadrigatus*", yet further in the same article she makes the conflicting statement that "circumstantial evidence points to several species of *Chiropsalmus* as being the cause of deaths in Queensland bathers". The problem in fact remains to be clarified. Not the least factor hindering the solution of the problem has been the rarity of Cubomedusae in collections.

The writer first became interested in this problem during the war years, when he was stationed at Palm Beach, north of Cairns, Qld., in the capacity of Regimental Medical Officer to a Battalion attached to an Australian Beach Group. Over a period from December 1943 to January 1944 about 100 instances of marine stingings occurred in personnel of the Services. The effects observed fell clearly into two clinical categories, and indicated that there were at least two agents operating in those waters. These stingings have been classified clinically into: (1) type A of Southcott and Powys (unpublished data, 1944; Southcott 1952) = Irukandji stinging of Flecker (1952*b*, 1952*c*) (a non-committal term based on the tribal name of a local group of Australian aborigines), or stingings without wealing but with severe general effects; and (2) type B of Southcott and Powys (unpublished data, 1944; Southcott 1952), or stinging with wealing but without severe general effects, referred to also by Flecker (1945*a*, 1952*a*, 1952*c*), McNeill (1945), and McNeill and Pope (1945).

Whereas it was apparent that type A or Irukandji stingings constitute a homogeneous group (caused by an organism that has not as yet been identified), yet it appears that more than one species of organism may be responsible for the type B stingings that occur in north Queensland waters. The effect of the sting of *Physalia* is well known, having been described graphically by Bennett (1834, 1860) and by various later writers. Flecker (1945*b*, in McNeill 1945, 1952*b*) has recorded the presence of the bluebottle or Portuguese man-o'-war (*Physalia* sp.) in the Cairns seas, despite an earlier assertion to the contrary (McNeill and Pope 1945).

II. Field Observations on Cubomedusan Stingings

In 1938, at Darwin, N.T., a fatal case of medusa stinging occurred in the local baths, the victim being a half-caste boy aged 12 years. It was stated that the medusa was still sticking to the victim when he was removed from the water (R. E. Murray, personal communication, 1944; Flecker 1952*a*). This medusa, although badly mutilated by its captors, is at present preserved in the School of Public Health and Tropical Medicine, University of Sydney (McNeill and Pope 1943*a*; Pope 1953). For the present it is not available for re-examination, being stored inaccessibly (E. R. Ford, personal communication, 1955). McNeill (in Flecker 1952*a*, 1952*c*) identified this medusa as *Chiropsalmus quadrigatus* Haeckel. As far as the present writer is aware, it is the only medusa anywhere in the world that has been preserved from a fatal case of stinging.

The present writer (1952) recorded and illustrated a Cubomedusa or "sea wasp", captured at Palm Beach, Cairns, on January 4, 1944. Unfortunately it was not possible to preserve this specimen. It was tentatively identified from sketches made at the time as a species of *Chiropsalmus* (McNeill 1945; Southcott

1952). The writer now believes that it was a part-grown specimen of *Chironex fleckeri*, gen. nov., sp. nov., described later in the present paper. The importance of that specimen lay in two features: (1) it was captured at a time when severe stingings were occurring in bathers in the same waters; (2) an experiment was made of its stinging powers, which served to help in identifying the types of stinging occurring at that time. This animal produced wealing (i.e. type B stinging) when applied to the skin. The following notes were made at the time.

"Specimen A7. Caught today (January 4, 1944) at Palm Beach. When brought to me it was not very well . . . It was absolutely transparent and devoid of coloration. When first seen, at about 3 p.m., the edges of the umbrella (this should have read velarium) were pulsating. After the trial of stinging recorded below the animal gave only a few pulsations. The animal had a number of long tentacles. [After taking the animal out of the water] I drew them across the back of my hand, without any result. I then drew them across the upper arm and forearm in half a dozen places. This was within a few seconds followed by a burning and prickling sensation, not very severe. After some minutes minute weals, as big as sago grains but flatter [i.e. 1-2 mm across], came out slowly, and increased for 30 minutes along the line of the sting, averaging about 5 mm. apart. There was practically no flare around these. They disappeared in the next half hour. There were no general symptoms at all . . .". On the following day the animal was found to be unable to sting, and appeared to have died. It decomposed soon after.

It was considered that the result of the above-mentioned experiment rules out the possibility that this species could have been responsible for the type A stingings in those waters. It was considered that this species of Cubomedusa could, on suitable skin, cause stinging with wealing or type B stinging—the latter being much less frequent locally than the type A stings.

The most substantial evidence therefore that a Cubomedusa could be responsible for fatalities in Australian tropic seas was that of the Darwin fatality in 1938 referred to above.

Little critical study appears to have been made of the effects of the stings of the Cubomedusae. The writer has recorded above an experiment in which an immature Cubomedusa (A7) was able to cause wealing on the thin skin of, e.g., the palmar aspect of his forearm, but was unable to produce any effect on the thicker skin of the dorsum of his hand. Later in this paper are quoted some field notes of Mr. L. Law, of Cairns, in which an immature Cubomedusa was able to produce pain without wealing or any external mark on the skin of the legs. Although therefore the Cubomedusae are generally recognized as causing stings of some severity, little exact knowledge is available. Pope (1947) recorded a sting with wealing in a "young schoolboy", but did not give any identification of the "sea wasp" (Cubomedusa) to which the sting was ascribed. Presumably it was a species of *Carybdea*. *Carybdea rastonii* Haacke, 1886, was originally described from St. Vincent's Gulf, S.A. It has since been recorded from the Philippines, Japan, and elsewhere in the Pacific Ocean. Cleland (1924) stated that Dr. C. J. Hackett (misprinted as Hachett) "informs me that near Glenelg [St. Vincent's Gulf, S.A.] the jellyfish *Charybdaea* sp. frequently stings bathers, though out of the water it can be handled with impunity.

In March 1924, he was stung probably by this species at Seacliff, South Australia. He first felt a pain like a pinprick, which was persistent. The pain extended along a line about 15 cm. (6 inches) in length over the shoulder. The line was the seat of an urticarial weal. The pain and rash persisted for twenty minutes. A warm solution of boracic acid and also sodium bicarbonate relieved the condition". Johnston (1943) mentioned the occurrence of *Carybdea* sp. in the "two gulfs" (Spencer's and St. Vincent's) in South Australia, stating that it occurs in numbers and that its tentacles are capable of inflicting severe stings on bathers. McNeill and Pope (1943*b*) stated that: "Minor stingings by carybdeid jellyfish are recorded from St. Vincent Gulf, South Australia, where it is reported to occur in schools of up to fifty in number. This would appear to be the most southerly record of stingings". The present writer has also been informed by local (i.e. St. Vincent's Gulf) yachtsmen, underwater swimmers, and others, of the stinging powers of the small "squarish jellyfish the size of an egg cup" but up to the present he has not had the opportunity of experimenting with it. Mr. D. C. Swan has presented the writer with sketches of *Carybdea* sp., from Glenelg, S.A., made on March 17, 1935, when it was common and caused stings among swimmers. Mr. Swan has informed the writer (personal communication, 1954), from notes made at the time, that the day (17th) was still and calm, and numerous specimens of *Carybdea* sp. were swimming in the sea in a zone about waist deep. This was subsequent to a storm, and at the time seaweed was piled up along the beach. Mr. Swan himself had been stung by the organism on March 3, 1935. He has commented that the animal is "almost invisible in the water—only parts visible are mauve-coloured tentacles and masses of gastric filaments and the black tentaculocysts. It swims actively at the surface, occasionally breaking the water and causing a ripple".

Mr. Swan has commented further: "This or a closely related species is common on West Australian beaches. I have seen them very thick on 1st January, 1939 at Busselton, W.A. The stings cause raised weals on human skin, and considerable oedema on e.g. lips and eyelids. They are also common on Perth beaches, but the picture is confused there by the presence of true "blue-bottles" (*Physalia*). However most Perth swimmers that claim to be stung by "blue-bottles" are probably stung by *Charybdea*, which in fact is commonly spoken of as a "blue-bottle" by swimmers. I have seen a boy pick up a *Physalia* in the surf and suffer cramps in the arms and armpits for a time thereafter."

"I have also seen a bigger Charybdeid come inshore after a blow at Bat Island (Purdy Archipelago, New Guinea). The beach was lined with them at low tide. This species [with a single tentacle to each pedalium—hence either a *Carybdea* or a *Tamoya*—R. V. S.] stung actively when handled (D. C. S., June 24, 1954)."

As can be seen from the foregoing account, such medusae may be extremely difficult to recognize in the water. Mr. H. M. Hale, Director, South Australian Museum, has informed the writer (personal communication, 1944) that *Carybdea* sp. (in St. Vincent's Gulf, S.A.) is so transparent that its presence is best detected by noticing its shadow on the underlying sand in shallow water, on a sunny day.

It may be concluded, therefore, that in general the Cubomedusae tend to cause severe or moderately severe stingings in man, judging by the Australian data available, which appear comparable to overseas experience with similar forms. The effects seen in human subjects could depend on such human factors as the age of the victim (influencing the thickness of the skin, among other factors), the protection afforded by swimming costume, and the degree of contact with the medusa. Factors concerning the medusa are, for example, the size of the animal, and the number and length of its tentacles; and seasonal and physiological factors could possibly play a part.

Turning to the effects of the tropical Cubomedusae in Australian waters, it is apparent that the problem remains a confused and difficult one, both from the medical and zoological aspects. A brief historical review of the medical zoological aspects of the problem in Australian waters was given by the present writer (Southcott 1952). It appears that the Australian beliefs on the effects of Cubomedusae in Australian waters are to a certain extent based on Philippine experience and beliefs, in conjunction with McNeill's identification of the Cubomedusa found at Darwin in 1938 as *Chiropsalmus quadrigatus*. In the Philippines *C. quadrigatus* is recorded as common, e.g. by Mayer (1910) and later authors. It is well recognized as causing severe stingings. Several authors—Old (1908), Light (1921), and Wade (1928)—have written on stingings by medusae in Philippine waters. Yet, as indicated above, there does not appear to be any record of the capture and preservation of the actual animal responsible for a fatality. Fatalities have in fact been ascribed to *Dactylometra quinquecirrha* (Desor) (Semaeostomeae) as well as to *Chiropsalmus quadrigatus*. The relevant literature on the medical aspects has been summarized by Flecker (1952*a*). The ascribing therefore of the deaths in Philippine waters to *C. quadrigatus* appears to be based mainly upon native lore, rather than to more direct scientific evidence. In view of the lack of precise knowledge of these forms and their effects, it is unwise to be dogmatic on this subject. In the present paper it is shown that a large species of Cubomedusa in northern Australian waters represents a previously undescribed form. The identifications previously given or suggested for Australian Cubomedusae as *Chiropsalmus quadrigatus* may need revising in the light of the present study.

There have been other reports of severe or fatal jellyfish stingings in Australia. Although most of the recorded fatalities have been in north Queensland waters, a few have been reported from the Northern Territory. Searcy (1907) recorded in lay terms a fatality in the Darwin baths, similar in nature to the 1938 fatality referred to above. Recently a similar fatality has occurred near Darwin, the victim being an 8-year-old boy, who was stung in shallow waters at Larrakeyah Beach, on February 28, 1955 (J. V. Quinn, personal communication, 1955; and daily press notices). This fatality has not previously been referred to in medical or zoological literature. The stinging was apparently extensive, and death was rapid. Unfortunately the organism responsible was not captured.

A number of similar fatalities has occurred in north Queensland waters. Many of these are referred to by the writers quoted above. The most recent was that of a boy aged 5 years (D. J. M.), who died rapidly after being stung in the sea at Cardwell, north Queensland, on January 20, 1955, at 9.35 a.m. (H. Flecker, personal communication, 1955, and daily press notices). The following day, January

21, at the instigation of Dr. Flecker, nettings were made in these waters by Inspector E. Anthony, formerly Superintendent of Police, Cairns. A series of Cubomedusae was obtained, and forwarded to the writer by Dr. Flecker. In the hair of the victim were a number of tentacles. Unfortunately these tentacles were not preserved, but it was stated that the tentacles in the hair looked the same as those on the Cubomedusae caught the following day. Furthermore, the mother of the dead boy affirmed that the large Cubomedusae were identical with the one responsible (Flecker, *in lit.*).

More recently, a large Cubomedusa was forwarded from Darwin by Dr. J. V. Quinn, formerly Medical Superintendent, Darwin Hospital; it was captured by Mr. J. R. McKay. This has proved to be the same species as those from Cardwell, and from the histological structure of its gonads is a mature female. It is the largest specimen of the series.

Among the Cardwell specimens were 4 that were nearly mature, 3 being female and 1 male, as well as 2 immature specimens. The writer has received also a juvenile specimen from Cairns, as well as certain field notes (see Section III) and photographs, from Mr. Lionel Law.

Examination of all these specimens (see Table 1) reveals that only one species, hitherto undescribed, is present. Furthermore, this species has a number of unusual features not previously recorded for the Cubomedusae, and from these it is possible to review the systematics of that group. It is with pleasure that the species is dedicated to Dr. Flecker, in recognition of his studies on this subject.

III. A New Genus and Species of Cubomedusa

(*a*) Genus CHIRONEX, gen. nov.

Definition

Large Cubomedusae in which the gonad is a lobulated structure projecting into the bell cavity from the subumbrella surface. Each of the four gonads (the "superior gonads") consists of a pair of hemigonads, arising alongside the perradial suspensoria, high within the bell cavity, near the origin of the manubrium. The lateral gonad (the gonad normally present in the Cubomedusae) absent, or else represented by an insignificant ridge arising at the interradius within the perradial stomach pouches.

Genotype: *Chironex fleckeri*, sp. nov.

(*b*) Chironex fleckeri, sp. nov.

Figs. 1-23; Plates 1-3 (except Plate 2, Fig. 2)

Description

Bell roughly cuboid, but with the apex of the exumbrella evenly rounded. Colourless in life, except for an occasional purplish tinge of the tentacles.* The jelly substance tough, gelatinous, and translucent, with whitish internal structures showing in the preserved specimens. Each corner of the box-like medusa is provided with a strong outstanding pedalium, provided with up to 12 tentacles. (The following description is largely taken from the holotype, a nearly mature male specimen (South Australian Museum Register Number H12) from Cardwell, Qld.)

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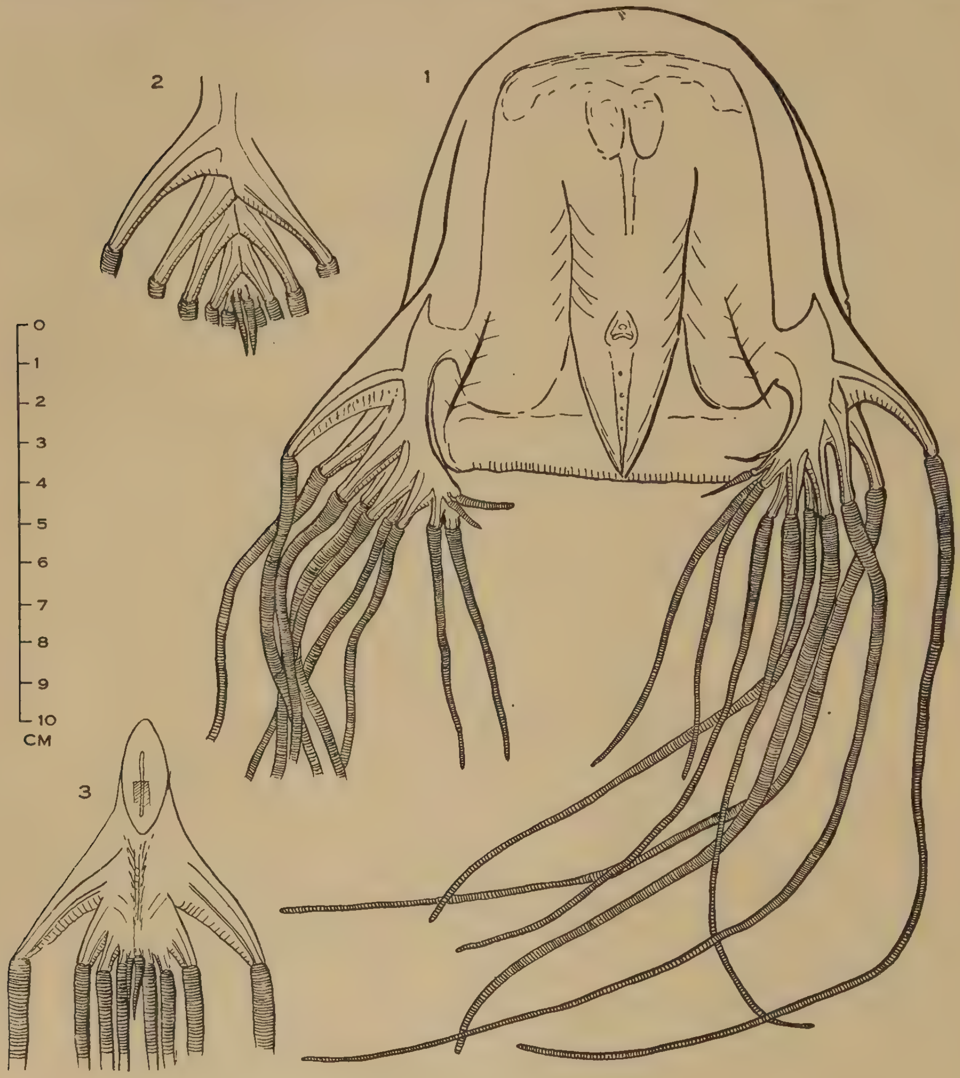
* The writer is inbedted to Mr. Lionel Law, of Cairns, for information on the coloration of these medusae (specimens from Cairns) (see his field notes, following), also for some photographs of living specimens. Figure 16 has been drawn from one of the latter. Dr. J. V. Quinn (personal communication) has informed the writer that the tentacles of the lost Darwin specimen (see Section III(*d*)) were "slightly bluish".



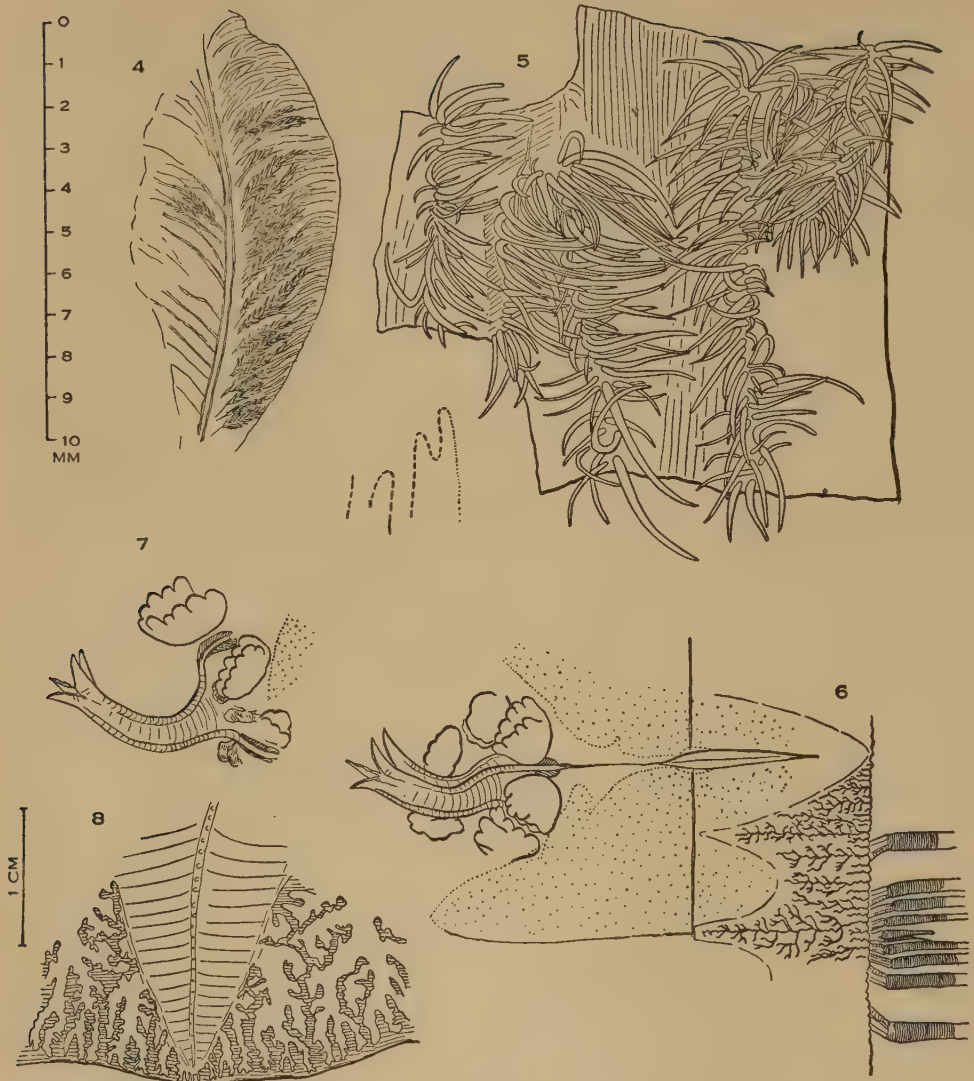
Figs. 1-3.—*Chironex fleckeri*, gen. nov., sp. nov. Holotype male S. A. M. H12, from Cardwell, north Queensland, January 21, 1955. Fig. 1.—Lateral (perradial) view of adult. Fig. 2.—External oblique view of pedalium and claws of adult. Fig. 3.—Internal (interradial) view of same. All figures to scale shown.

Bell height 118 mm (measured with the velarium extended, as in Fig. 1). Distance from edge of velarium to rhopalar niche, 42 mm. Height of bell to level of rhopalar niche, 76 mm. The external sides of the box-like bell are divided by grooves into lappets, but the surface of the exumbrella is smooth, except for the microscopic warts in the region of the rhopalium (see below).

Velarium wide, width 28 mm at its widest point; opposite the adradial lappets it is 25 mm wide; the velarium width therefore is about one-quarter of the bell height. As is usual in the Cubomedusae, in life the velarium is contracted across the mouth of the bell cavity, partly occluding it (Fig. 14 shows this in an immature specimen (S. A. M. H16 from Cardwell), as does also my previous figure (Southcott 1952; A7 from Palm Beach)). The velarium is supported by 4 spindle-shaped perradial frenula on the inner aspect of the perradial lappets (shown in Figs. 6 and 9). The frenula are 60 mm long by 6 mm wide, and are attached along their length by about one-third of the circumference. The perradial lappets are pointed and project to the edge of the velarium, being supported internally by the perradial frenula. The adradial lappets are rounded, and their substance becomes gradually thinner toward the velarium. In each quadrant of the velarium there are numerous non-anastomosing velar canals or diverticula, outbranches of the gastrovascular space. The thin transparent ribbons of velar substance between these velar canals give the appearance of ramifying dendritically (Figs. 6 and 8).

The perradial sense organ is set in a niche in a small flattened boss, as figured (see Figs. 9-11). The boss is 8 mm across by 11 mm high, and is provided with a few scattered minute warts, these becoming more numerous on the lower lip of the sensory niche. The mouth of the niche is 7 mm wide at its widest point, near its outer surface, and faces downwards and outwards at an angle of about 45°. The upper lip is overhanging, and has a sharp sinuous inferior border, resembling a human mouth with depressed corners. The lower lip is evenly rounded, and runs smoothly into the niche. The sense organ may be seen from the outer aspect only by looking upwards obliquely through the mouth of the niche. It hangs down from the roof of the cavity, articulating upon a constriction on a distinct pedicle, through which run vascular and nervous channels. The sense organ resembles that of other Cubomedusae. There is a terminal abaxial concretion and 6 eyespots, of which only the largest (the distal median) may be properly designated an eye. Its lens may be bituberculate (see Figs. 12 and 13). The eye normally faces downwards and medially, and therefore faces towards the bell cavity. The other eyespots have no lens. The proximal median eyespot is next in size, and is flanked by the 4 smaller patches of retinal pigment.

A pedalium originates at each interradial corner of the animal. It is long, thick, tough, strong, and outstanding, and is somewhat laterally compressed. The pedalium soon branches into up to 12 branches or claws, each provided with a tentacle. The claws, like the root of the pedalium, are smooth and rounded on their outer surfaces, but below are sharp. These claws gradually decrease in size outwards along the pedalium. The 1st claw is the most outstanding, and is unpaired. The others are paired, except possibly the minute terminal claw. The pedalium is 11 mm thick across the root, and the root here has a vertical diameter of 22 mm. Each claw contains a wide canal, somewhat compressed laterally. In the larger claws the vertical diameter of these canals is 3 mm. The canals are an extension



Figs. 4-8.—*Chironex fleckeri*, gen. nov., sp. nov. Fig. 4.—The pinnate gland viewed from its inner aspect (to scale on left). Fig. 5.—Phacelli with gastric cirri, to same scale. Inset (bottom left), plan of the origin of the cirri on the phacelli figured. Fig. 6.—Internal (subumbral) surface of the bell cavity of the adult, with the vertical axis of the animal laid horizontally. The spindle-shaped frenulum (upper right) overlies the rhopalium in this figure, and is perradial; it is shown connecting by the suspensorium to the perradial border of the manubrium, which eventually ends in the cruciform lips of the manubrium at the left side of the figure. The cock's-comb-like structures are the superior gonads ("gastric saccules") originating alongside the perradii. The small feathery structure straddling the upper part of the perradial borders of the manubrium is the pinnate gland (lying between the superior hemigonads). On the right, the claws and tentacles of the pedalium, from the inner aspect, are shown projecting on the other (umbral) side of the velarium. The centre of the pedalium is at the interradius. The gastrovascular space

[*For continuation see opposite page.*]

of the gastrovascular space of the organism, and connect with the cavity of the tentacles. In the root of the pedalium the canal has an upward projecting spur or "corniculum" shown in Figures 1, 14, and 16; on the inner side of this where the pedalium canal connects to the perradial gastrovascular space (stomach pouches) the canal is constricted. Each claw of the pedalium widens a little at the origin of the tentacle. The tentacle is hollow, thick, and strong, and tapers distally to a blunt point. Each tentacle is provided with rings of nematocysts, arranged in inner and outer groups alternately (Plate 1, Figs. 1-2). In the preserved nearly mature adults from Cardwell the tentacles are up to 30 cm long. (It is probable that these tentacles have considerable powers of extension and contraction. Thus specimen A7, which the writer believes to be of the same species, had tentacles about 30 cm long when alive, with its bell only about half the linear dimensions of the type specimen. See also the notes of Mr. Law following, in which he describes tentacles up to 4 ft long in a juvenile specimen.) The wide cavity of the tentacles is lined with a broad epithelium. In preserved specimens the tentacles are frequently a flattened oval in cross section, and when thus, may be as much as 5·5 mm wide. In preserved specimens it is not difficult to detach the tentacles from the claws. The branches of the pedalium are symmetrical, except possibly terminally, where they may be asymmetrical both in size and in the manner of their origin (see Figs. 1-3). The terminal tentacles may be only a few millimetres long. In a paratype female specimen, S. A. M. H13 (bell height 120 mm, width 100 mm), there is a minute flattened central bud, 3 mm long by 1 mm wide in between the 5th pair of claws (i.e. 10th and 11th claws), on one pedalium, and on this bud the development of rings of nematocysts is just discernible. On the other pedalia of this specimen this 12th bud is present, but even smaller.

The manubrium (proboscis or oesophagus) (Figs. 6 and 7) is long, 5 cm long by 12 mm wide, and roughly square in transverse section. Its edges are perradial and provided with rounded columns, which extend inferiorly into the folded lanceolate perradial lips. The perradial columns continue superiorly into the narrow perradial laminar suspensoria (mesogonia or "gastric mesenteries"), which continue to the perradial frenula.

Alongside each suspensorium is a pair of large cock's-comb-like lobes, projecting into the bell cavity. These lobate organs have been referred to in other species as "gastric saccules", but histological study by the writer, described below, has shown that they constitute the functioning gonad in this animal. The term "superior gonad" will therefore be used here in place of "gastric saccules". At the normal site of the gonad in the Cubomedusae, i.e. along the interradial septum within the perradial stomach pouches, there is only at most a narrow ridge (see

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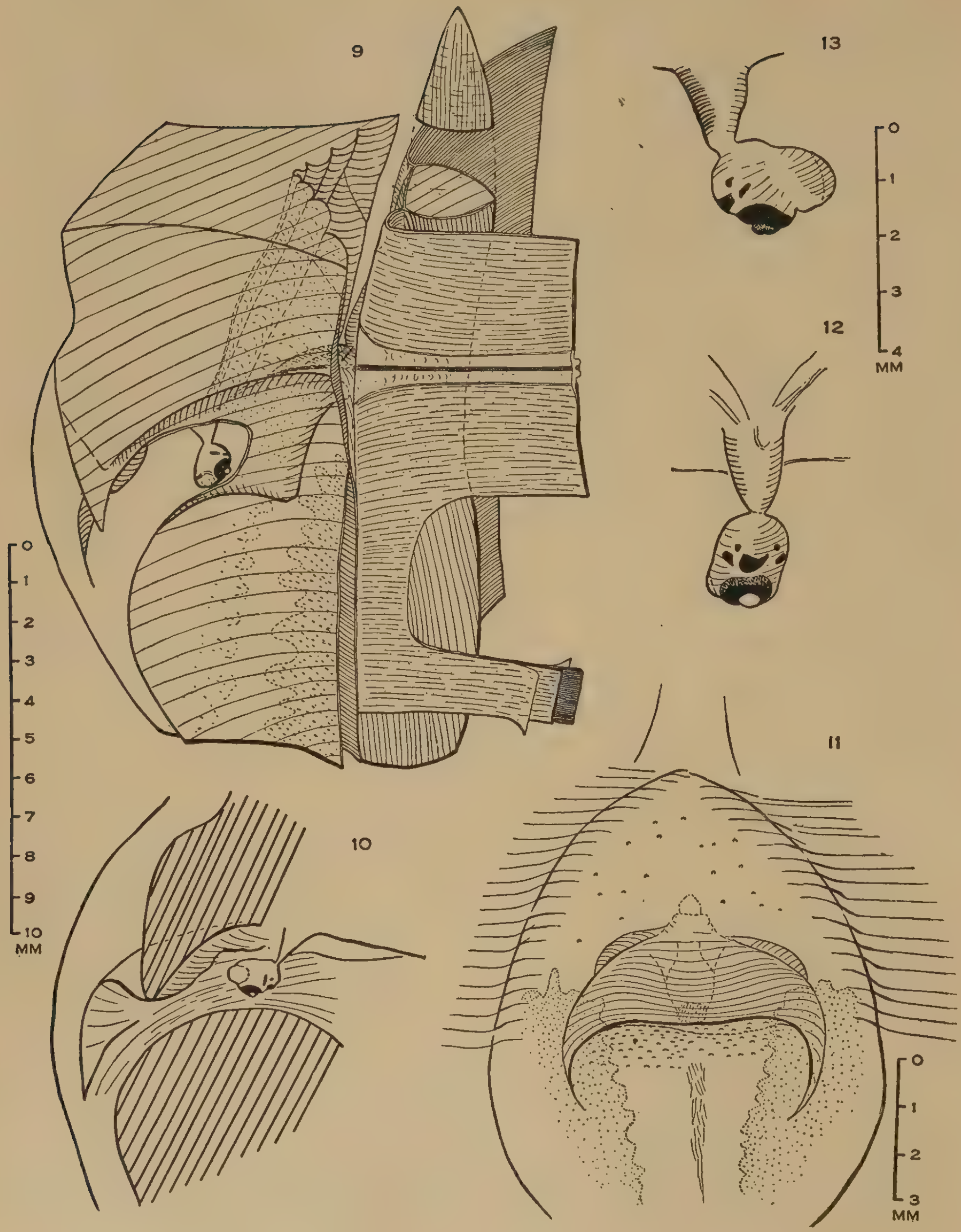
Figs. 4-8 (*Continued*)

is indicated in stipple. The vertical line running through the frenulum indicates the "nerve ring". Fig. 7.—Oblique view of the structures shown on the left of Fig. 6. The manubrium, superior gonads, and pinnate glands are shown. The small additional protuberances near the origin of the manubrium in this figure are the thin-walled pouches of cirri. Figs. 6 and 7 are not to scale. Fig. 8.—Detail of tip of perradial lappet (umbral aspect) and branching canals (the white spaces in the figure) of adjacent velarium, to scale on left.



Figs. 9-13.—*Chironex fleckeri*, gen. nov., sp. nov. Fig. 9.—Dissection of rhopalar niche and adjacent perradial part of exumbrella and subumbrella in an adult, to show the relationships of the gastrovascular space; to scale on left. The mesogloea is cut into various surfaces (broad-hatched) to display the parts. The boss on the left side of the figure is the external boss of the rhopalium, and the mouth opening into the rhopalar niche is cut vertically. Part of the niche

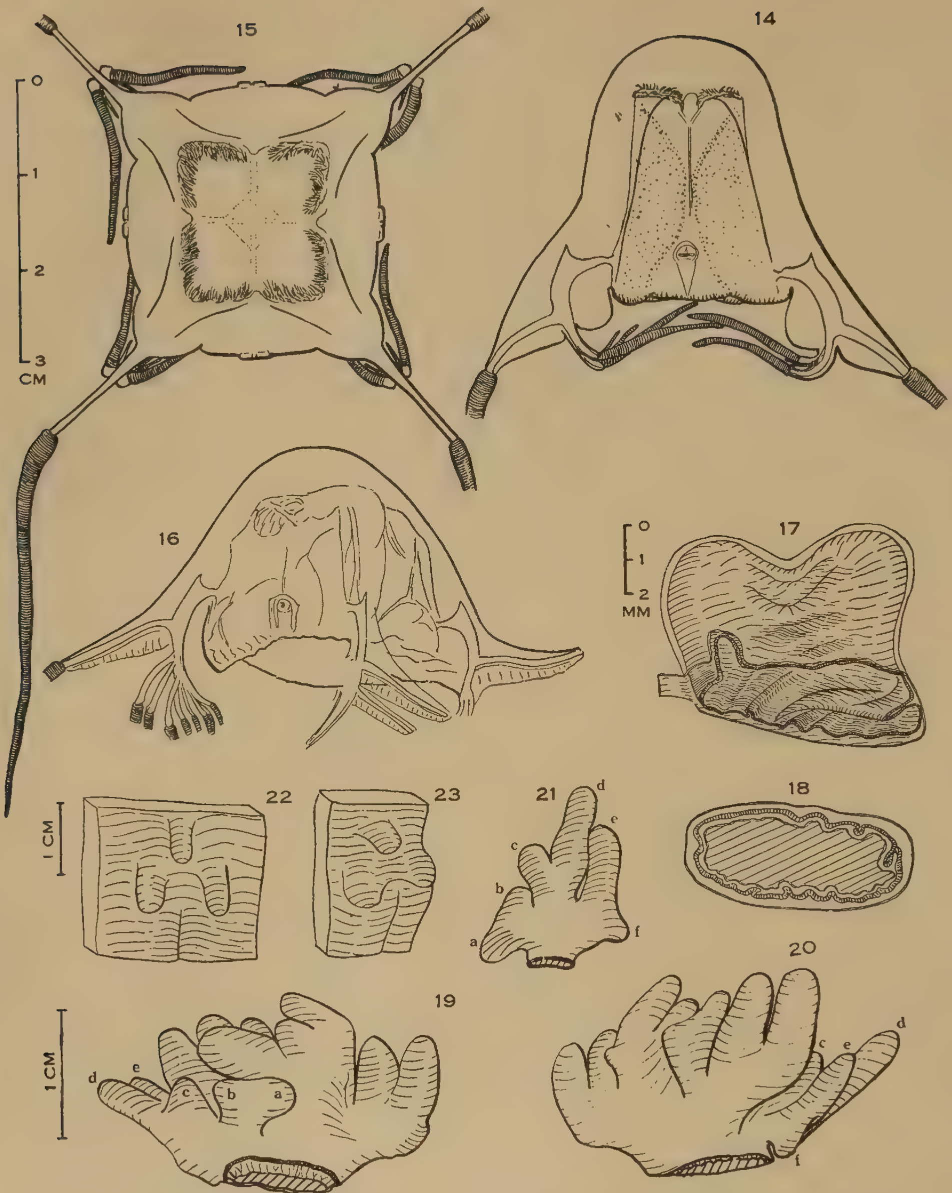
[*For continuation see opposite page.*]

below). For this, and for the normal gonad in the Cubomedusae, the term "lateral gonad" will be introduced. In the description of *Chironex fleckeri* the term "gonad" (or "hemigonad") will refer to the superior gonad, unless otherwise specified.

Each of the four superior gonads consists of a pair of hemigonads. In the nearly mature specimens from Cardwell the hemigonad has the typical lobulate cock's-comb-like structure that Mayer (1910) has described for *Chiropsalmus quadrigatus*. At this stage in *Chironex* the hemigonad is about 2 cm long. From its sharper free edge there are about a dozen small lobules projecting (Figs. 6, 7, and 17). In the mature female (specimen S. A. M. H19 from Darwin) with bell height (to rhopalar niche) 98 mm, bell width 130 mm, the hemigonad is divided into 4 main lobes, each of which carries about a dozen digitations, which are either single or in groups of 2, 3, or 4, there being 40-50 "fingers" to each hemigonad (Figs. 19-21). In the juvenile stages available (specimen S. A. M. H17 with bell height (to rhopalar niche) 23 mm and bell width 23 mm, and specimen S. A. M. H16 with bell height (to rhopalar niche) 27 mm and bell width 27 mm) there is at first no sign visible of the superior gonad (nor of the lateral). At the first stage at which the superior hemigonad is present in the available specimens (specimen S. A. M. H18) the superior hemigonad is represented by a group of 3 tubercles (Figs. 22 and 23). The structure of the superior and lateral gonads are considered further below.

Figs. 9-13 (*Continued*)

is cut away to display the sense organ hanging on its pedicle. The rhopalar niche seen through the mesogloea is shown in stipple. In the mesogloea below the rhopalar niche the digitations (stippled) at the edge of the gastrovascular space show, extending from the cleft at the bottom of the figure. This part of the gastrovascular space is shown communicating with the part above the rhopalar niche, indicated by the large cleft at the top of the diagram. The outer surface of the gastrovascular space in this situation is sculptured as shown, the grooves running down to the base of the sensory pedicle. The large pointed vertical column on the right is the frenulum, shown partly cut away in its upper part. Most of its surface is subumbral. At the level of the section it is prismatic, with convex sides. Its perradial outer surface, above the rhopalium, is in the gastrovascular space, and bellies down to the "supracavernal floor" overlying the roof of the rhopalar niche. The suprarhopalar and infrarhopalar parts of the gastrovascular space connect around the root of the rhopalium, below which the frenulum of the subumbrella and the exumbrella connect along the ladder of mesogloea outlined by the digitations of the perradial edges of the subrhopalar part of the gastrovascular space. The subumbrella unites with the frenulum along the latter's paraperradial borders. At the bottom right of the diagram the subumbrella has been displayed into its component layers. These are, from within out: epithelium of subumbrellar surface (bell cavity); circular muscle layer; mesogloea layer; epithelium of gastrovascular space. The circular muscle layer is incomplete on either side of the "nerve ring", shown by the denser line running horizontally across the subumbrella, and there the mesogloea is thickened (see small projections investing the "nerve ring" on the right). The "nerve ring" (shown also in Fig. 6) runs across the roof of the sensory niche, under the convoluted "supracavernal floor", to the sensory organ. Fig. 10.—Vertical section through another rhopalar niche, where the eye of the sensory club looks directly downwards. The cut surface of the mesogloea is indicated by the oblique shading. Same scale as Fig. 9. Fig. 11.—External view of rhopalar boss, to scale on right. Underlying structure is also shown. Below the mouth of the sensory niche (thick line), the digitations of the perradial edges of the gastrovascular space are shown in stipple. Between these is a clear layer of mesogloea, where the exumbrella unites with the frenulum. Figs. 12 and 13.—Sense organ, viewed from the subumbral and lateral aspects respectively, to scale on right.



Figs. 14-23.—*Chironex fleckeri,* gen. nov., sp. nov. Fig. 14.—Lateral (perradial) view of immature specimen at the 5-clawed stage of the pedalium (S. A. M. H16 from Cardwell). Fig. 15.—Same, from above. (Figs. 14 and 15 to scale on left.) Fig. 16.—A juvenile specimen, rather more mature, drawn from a photograph of a living specimen, by Mr. L. Law (S. A. M. H18; see text). Fig. 17.—Adult testis ("gastric saccule"), to scale shown. The core of mesogloea with its adherent epithelium has fallen out. The drawing shows the external limiting membrane, and the underlying thicker more folded testicular layer. Fig. 18.—Diagrammatic cross section of preceding, illustrating the mesogloeal core *in situ* with the adherent internal epithelium,

[*For continuation see opposite page.*]

The gastric cavity is short and broad. Inferiorly it communicates with the cavity of the manubrium (oesophagus), and laterally, at the perradii, it communicates through the gastric ostia (pylori) with the perradial stomach pouches. The gastric cirri are simple, pointed, unbranched, to 10 mm long, but mostly rather shorter. In their upper part they are gathered into 4 large phacelli. In these the cirri originate along a series of vertical ridges together with their connecting loops (see Fig. 5 and inset). Inferiorly the cirri are gathered into little thin-walled pouches that project into the bell cavity at the root of the manubrium, between the suspensoria (these can be seen in Fig. 7). Straddling the perradial suspensoria, inside the oesophagogastric junction, is a "pinnate gland" (Figs. 4, 7, and 8), presumably of digestive function. In structure it is a pinnate collection of villi, its lining epithelium consisting of many close-packed columnar cells with dark-staining elongated nuclei (Plate 2, Fig. 1). These glands are each in the sac-like space which runs into the upper corners of the oesophagus.

There are 4 perradial stomach pouches (stomach pockets, pocket arms, gastric diverticula, gastrovascular spaces, etc.). These are separated from each other by the narrow interradial septa (interradial vascular lamellae), except at the root of the pedalium where they communicate with the cavity of the pedalium as recorded above. Above each rhopalium a projection of the stomach pouch extends out to communicate with the sense organ. Below each rhopalium the gastrovascular spaces sweep around and inferiorly, where they end, each as a narrow cleft with dentate edges, separated somewhat from its fellow across the perradius (see Figs. 9 and 11). The anatomy of the rhopalium and adjacent structures is explained in the legends to Figures 9-11.

The structure at the edge of the perradial stomach pouch, at the interradius, is described further below.

(c) *The Structure of the Immature Stages*

In these there is the same general (though more slender) form as occurs in the mature stages. The major differences lie in the immaturity of the gonad, and the reduction of the number of claws on the relatively more slender pedalium. It appears that a convenient method of classifying these stages is by the number of claws to the pedalium.

The earliest stage in this series (specimen S. A. M. H17 from Cardwell) has the pedalium at the 3-clawed stage (not figured in this paper). Bell height is 23 mm, width 23 mm, height from apex to rhopalar niche 19 mm, rhopalar niche to velarium edge 4 mm. The rhopalar niche is more open than in the mature or nearly mature forms. No sign of a superior gonad is visible, nor is there any sign of a "lateral gonad" to macroscopic examination.

Figs. 14-23 (*Continued*)

the gonadal layer, and the external limiting membrane. Figs. 19-21.—Part of the ovary of the most mature specimen of the series (female A71 from Darwin), to scale on left of Figure 19. The part illustrated is about one-quarter of a hemigonad. The lettering identifies the branching digitations between the drawings. Figs. 22-34.—The hemigonad of an immature specimen (S. A. M. H18) at the 3-tubercle stage, front and oblique views, to scale on left.

A juvenile with the pedalium at the 5-clawed stage is among the Cardwell specimens (S. A. M. H16) (Figs. 14 and 15). Bell height is 27 mm, bell width 27 mm, height from apex to rhopalar niche 23 mm, rhopalar niche to velarium edge 4 mm. The rhopalar niche is rather open, as in the preceding stage. There is no sign of either a superior or "lateral" gonad.

Two other juveniles are also referred to this species. Specimen A7, from Palm Beach, of January 4, 1944 (not preserved) was referred to above. Although it was not examined at a time when the writer was familiar with the anatomy of these forms, yet it is believed, from sketches made at the time, that it may be referred to this species with reasonable confidence. Six claws and tentacles were noted on examination of the living specimen; it is possible that minute claws with short tentacles could have been overlooked. The height was approximately 52 mm, width approximately 50 mm. A sketch made after death, with the animal turned "inside out", shows a large smooth swelling present at the site where one could expect to find the superior gonad. A further comparable specimen (S. A. M. H18 from Cairns, preserved) is available. This has the pedalia damaged, so it is not possible to tell the number of claws. The bell height was approximately 50 mm, width approximately 55 mm (the preservation was poor). In this specimen the superior hemigonad was at the 3-tubercle stage.

(*d*) *Localities*

Specimens referred to *Chironex fleckeri* have been taken from localities shown in Table 1.

(*e*) *Some Field Notes on* Chironex fleckeri *in the Cairns Region*

Mr. Lionel Law's notes on these medusae read as follows: "These jellyfish are of a tough four-sided structure, and each has four main tentacles (i.e. pedalia—R.V.S.), one at each corner; each of these [pedalia] branches into six or seven ribbon-like tentacles. Whilst the [pedalium] is transparent, the ribbon is rather opaque with fine horizontal black lines. Some of the tentacles are of a purplish colour but most are white. The tentacles have ranged in length from half an inch to four feet. The tentacles, though tough, break off in the net and in the aquarium."

"Specimen 3863 [now S. A. M. H18] (preserved) stung a middle-aged man on the second finger, 7th January, 1953. Although the sting was severe, and throbbing continued for two hours afterwards, it subsided in approximately eight hours. The effect was purely local and no mark was visible."

"This same victim was stung on the legs later in the day by a similar specimen (3863A, not preserved), 2½ inches [6·5 cm.] in diameter, with tentacles 4 feet [120 cm.] long. Eight tentacles were wrapped around one ankle and leg, and a lesser number around the ankle of the other leg. The sting was immediate and very severe. Pain was continuous for three hours and was intermittent for a further six hours. Though actual vomiting did not occur, nausea was present for twelve hours. Despite the severity of the sting, no mark at all was visible."

"It must be borne in mind that the victim in this case is a middle-aged man in excellent condition who wears short trousers at all times."

TABLE 1

DETAILS OF SPECIMENS

Specimen*	Description of Specimen	Locality	Date and Collector	No. of Claws to Pedalia	Bell and Apex to Niche Heights (mm)	Bell Width (mm)
Cairns region, north Queensland						
A7		Palm Beach	4.i.1944 (R. V. S.)	6, 6, 6, 6	*c.* 52(45+7)	*c.* 50
S. A. M. H18		Cairns	7.i.1953 (L. L.)	—, —, —, —	*c.* 50	*c.* 55
3863A†		Cairns	7.i.1953 (L. L.)	—, —, —, —	*c.* 65	*c.* 65
Cardwell, north Queensland‡						
S. A. M. H12	Near mature, male			11, 11, —, —	118(76+42)	100
S. A. M. H13	Near mature, female			12, 12, 12, 12	120	100
S. A. M. H14	Near mature, female			10, 10, 10, 10	110(90+20)	—
S. A. M. H15	Near mature, female			10, 10, 9, 9	65(55+10)	70
S. A. M. H16	Immature, no gonad			5, 5, 5, 5	27(23+4)	27
S. A. M. H17	Immature, no gonad			3, 3, 3, 3	23(19+4)	23
Darwin, Northern Territory§						
S. A. M. H19	Mature, female			10, 10, 10, 10	148(98+50)	130

* Specimens S. A. M. H12 to H18 have been deposited in the South Australian Museum.

† Not preserved; photograph only examined.

‡ Coll. E. Anthony, January 21, 1955; forwarded by H. Flecker.

§ Coll. J. R. McKay *c.* April 17, 1955; forwarded by J. V. Quinn. An earlier specimen of comparable size, coll. *c.* March 18, 1955, J. R. McKay, was lost in despatch.

(*f*) *The Identification of the Gonad in* Chironex fleckeri

In attempting to classify this medusa the writer initially found difficulty in identifying the gonad. Although he was inclined to ascribe this to inexperience, an examination of some South Australian specimens of *Carybdea* sp. (probably *C. rastonii* Haacke, 1886) showed that the gonads were easily identifiable, as expected from standard descriptions.

As stated in Section I, tentative efforts have been made by some previous writers to identify what was possibly the same species of medusa (e.g. the one figured by Pope (1953)) with *Chiropsalmus quadrigatus* Haeckel, 1879. In his original account Haeckel (1879) stated of the spirit-preserved type specimen "Die inneren Organe (Magen, Gonaden, Subumbrella) fehlen". Presumably it was a damaged specimen. It measured 50 mm high by 45 mm broad. Its pedalium was 4-clawed. Mayer (1910), in describing a series of *C. quadrigatus* from the Philippines, describes the mature pedalium as having 8 or 9 claws. His "apparently mature" specimen was 97 mm high by 100 mm wide. Mayer refers to a specimen with the pedalium at the 4-claw stage as having "no gastric saccules and no gonads". A specimen figured by him, 70 mm high by 80 mm wide, had "well-developed but immature gonads. With large cock's-comb–shaped gastric saccules". He states also that: "The 8 leaf-like gonads are well developed and resemble those of *Carybdea* but are not yet mature. They arise on both sides of each interradial septum and project into the wide perradial stomach pouches". Mayer also figures the gonads of *Chiropsalmus quadrumanus* (Müller 1859), the genotype of *Chiropsalmus* L. Agassiz, 1862, showing them as the typical replicated leaves originating within the stomach pouches at the interradial septa.

The difficulty in identifying the gonad macroscopically in the large Australian Cubomedusae examined was therefore surprising. In order to locate the apparently missing organ histological sections were cut through the corner of the subumbrella and bell, to include the lateral edges of the perradial stomach pouches, at about the level of the middle of the interradial septum—a situation where the section should, judging by the structure of other Cubomedusae, have transected the gonad. Despite this there was no leaf-like gonad found. In some specimens a narrow projecting ridge was found, at most about 0·4 mm broad, where the gonad was expected; in others there was nothing. It was quite clear then that the mature or nearly mature Australian Cubomedusa under examination was distinct from previously described Cubomedusae.

Attention was directed to the "gastric saccules". Histological examination of the first one examined of these was strongly suggestive of any ovary. The other specimens were then examined similarly. One of the five large specimens showed the histological features of a testis in the "gastric saccule", in the others, of an ovary. These features are described further below.

(*g*) *Histological Methods*

In the histological studies the sections were cut at 5-10 μ thick after paraffin embedding; and stained routinely with Harris's haemalum, and counterstained with 0·1 per cent. alcoholic eosin. The only exception to this was with some of the sections of the (superior) ovary, where the tissue was stained with Weigert's iron haematoxylin, without counterstaining (shown in Plate 3, Fig. 4).

(*h*) *The Structure and Histology of the Superior Gonad*

Each lobule or digitation of the gonad consists of a solid core of mesogloea, over which are three layers of tissue. These are, in order from the outside, the external limiting layer, the actual gonadal layer, and the internal epithelium. A space appears between the gonadal layer and the internal epithelium. Once a lobe or digitation is transected it is usual for the mesogloeal core, with its attached internal epithelium, to drop out (Fig. 17). This space appears to be natural, and to be responsible for the previous name "gastric saccule" bestowed on this organ in *Chiropsalmus*. In histological section a space may appear between the external limiting layer and the gonadal layer, but this appears to be an artefact.

The external limiting membrane (Plate 2, Fig. 3; Plate 3, Figs. 1 and 3) consists of a double layer of rather flattened cells, with small rounded or irregular nuclei and poorly staining vacuolated cytoplasm, enclosing what appears to be a thin axial plate, 8-10 μ thick (so named by analogy with the similar structure in the gonadal layer). Mostly the axial plate appears structureless in section, but in places it appears fibrillary. The whole membrane is 12-30 μ thick where narrowest.

The mesogloeal core of the lobule is faintly fibrillary in histological section, or practically structureless. No cellular elements can be seen in it. Firmly attached to the core is a thin unicellular epithelium, sitting on a thin basement membrane. The epithelium occasionally presents a cubical or more heaped up appearance. The nuclei are darkly staining, rounded or irregular. The cytoplasm is faintly basophil, granular, and occasionally vacuolated. A good deal of replication may occur with this epithelium. In the section the core is rather shrunken, and a number of spaces lined with this epithelium appear within it. The gonadal layer does not penetrate either into the spaces within the core, or in the surrounding space, and it would appear that the space seen in section between the gonadal layer and the internal epithelium is natural.

(i) *The Testicular Layer* (Plate 2, Figs. 3 and 4).—The testicular layer gives the appearance of being a further development in structure of the external limiting membrane, but thicker, and mostly showing extensive replication. The axial plate is much thicker, and is sandwiched between an adherent epithelial layer on either side. The cells of these attached epithelia are similar to those of the external limiting membrane. The nuclei are rounded or irregular, 2-4 μ across. The cell outlines are indistinct, and the cytoplasm is poorly stained and occupied by numerous large vacuoles. Again the strands of cytoplasm tend to condense around the nuclei. The apical layers of cytoplasm are finely granular; the basal are clear. The outer layer consists, in its simplest form, of a single layer of cells, with the nuclei set about one-third of the way below the surface. The inner layer consists of several layers of cells. The feet of these columnar cells condense to a layer that lies on the axial plate. The whole membrane, at its thinnest, is about 50 μ thick, and the axial plate may be as little as 7 μ thick, but these figures are generally doubled or trebled.

The axial plate contains branching columns of maturing sperm cells. These tend to form tubules of cells with a large oval or irregular nucleus, and a small amount of rather darkly staining cytoplasm. In section these anastomosing columns may show as rosettes, of up to a dozen cells. The centre of the rosette may show a collection of coarsely granular basophilic material among the basophilic cytoplasm, or there may be a clear space. The nuclei are about 3-4 μ long on an average, some up to 5 μ. In some cells chromosomal division may be seen taking place.

(ii) *The Ovarian Layer* (Plate 3, Figs. 1-4).—In the female the structure is similar to that in the male, apart from the actual ovarian cells. The oocytes develop within the axial plate. In the nearly mature Cardwell specimens (Plate 3, Figs. 1 and 2) the oocytes show in section as large oval cells, up to 20 μ long, containing large clear nuclei up to 10 μ long, within which are large rounded nucleoli about 5 μ across. The cytoplasm of these cells is packed at this stage with fine basophilic granules (yolk granules). Alongside the axial plate, in the depths of the supporting epithelial layers and frequently within the scalloped edge of the axial plate, are cells with dark-staining nuclei but with little cytoplasm. These cells may occur in groups of three or four, but are usually single.

At a more mature stage (S. A. M. H19) (Plate 3, Figs. 3 and 4) the oocytes increase greatly in size, and the cytoplasm becomes packed with coarser yolk granules, now eosinophil. These cells now assume a rather cubical structure from the denseness of their packing. At this stage they are 50-80 μ across. Their nuclei are oval or occasionally irregular and average 20-25 μ across, occasionally up to 30 μ along their long diameter. The nucleoli are rounded, 6-7 μ across, and frequently eccentric or marginal within the reticular nucleoplasm. Within the nuclei there may be also one or two marginal vacuoles. The axial plate of the ovary is no longer recognizable as such, but its remains lie between the ripe oocytes, its substance being interspersed by numerous small spherical bodies, 3-5 μ across, packed with eosinophil yolk granules (hence "yolk spherules"), together with a few cells with small nuclei and scanty cytoplasm. It appears clear that here the formation and carriage of the yolk granules has assumed predominance.

Presumably the ripe ova are liberated by the rupture of the external limiting membrane, into the bell cavity. The same would apply in the case of the sperm cells. This stage has not been reached in these specimens.

(*i*) *Comparison with the Histology of the Gonads in Other Cubomedusae*

Müller (1859) described and figured the histological appearances of the ovary in *Chiropsalmus quadrumanus* (Müller). Müller's original account is not available to me, but it is quoted in Thiel (1936), and the figure of the ovum given. These correspond to the mature ovum in *Chironex fleckeri*—the large cell, packed with yolk granules, and with a large pale nucleus containing a well-marked nucleolus. Claus (1878) described the histology of the gonads in *Carybdea marsupialis* (Linnaeus), and Hertwig and Hertwig (1878) (according to Thiel 1936) described the same species. Conant (1898) described briefly the histology of the gonads in *Carybdea xaymacana* Conant, 1897.

From these accounts there appears no significant point of difference from the histological structure of the (superior) gonad in *Chironex fleckeri*. The writer has made an attempt to compare the histological features of *Chironex* with those in *Chiropsalmus*. The United States National Museum, to which application was made for help, generously forwarded two of their three specimens of *Chiropsalmus quadrumanus*. Details of these specimens were: (1) specimen No. 43044, from Biloxi, Mississippi, Caribbean Biological Laboratory, coll. et don. H. B. Bigelow (1931); (2) specimen No. 42157, Louisiana coast, Southern Biological Supply Co., (P. Viosca, Jr.), 1921 or 1923 (also identified by H. B. Bigelow). Both specimens were about 3½ cm across (they were somewhat distorted in fixation).

Examination of these specimens of *Chiropsalmus quadrumanus* showed that the lateral gonad was present, and was as shown in Mayer's (1910) account. Although Mayer (loc. cit.) described the "gastric saccules" (superior gonads) as finger-like in this species, in the two specimens the writer has examined the superior gonad consists only of a pair of solid tubercles, each corresponding to a hemigonad. Histological examination of this shows only a thin epithelial layer adherent to a solid gelatinous matrix. This did not agree with Mayer's (1910) description: "each of these (perradial stomach) pouches gives rise to 2 finger-shaped, hollow, hernia-like sacs which project from the subumbrella side into the cavity of the bell; these 8 sacs are situated very near base of stomach".

Possibly the difference observed can be ascribed to the fact that Mayer (1910, p. 515) was dealing with larger specimens. Thus he records the bell as about 140 mm wide and 100 mm high. Nevertheless, histological examination of the lateral gonads in the two U.S.N.M. specimens reveals that they are apparently mature males (see Plate 2, Fig. 2). The testis is replicated, with layers from 20-60 μ thick. The layers consist of a mass of mature or nearly mature sperm cells, with some tendency to rosette formation. The appearance was in fact rather more mature than in the testis of the only male of *Chironex fleckeri* available.

As indicated, from long preservation and distortion as well as some damage, the specimens of *C. quadrumanus* were not ideal for histological and other examination, and possibly further comparisons can be made when fresh material becomes available. A histological study of the "superior gonad" in large specimens of *Chiropsalmus quadrumanus* should be of considerable interest.

However, that the "gastric saccules" in *Chironex fleckeri* are indeed the gonads appears beyond dispute, from the above histological studies. Apparently in that species the superior gonads are the only functioning gonads.

(*j*) *The Histology of the Interradial Septum and the "Lateral Gonad" in* Chironex fleckeri (Plate 1, Figs. 3-5)

The umbrella is united to the subumbrella by the interradial septum (cathammal plate; interradial vascular lamella of Conant). Even in the nearly mature specimen this is quite narrow, about 60 μ across. It is composed of the same faintly fibrillary mesogloea that constitutes the substance of the bell, but across the septum is a series of spaces that contain a few nuclei, and which presumably represent vascular channels. On either side the septum expands, externally into the thick layer of the bell substance, and internally to the thin layer of mesogloea supporting the subumbrella.

The marginal part of the stomach pouch (the only part of this cavity that has been examined in detail histologically) is lined with a peculiar columnar epithelium (Plate 1, Figs. 4 and 5). That on the umbrellar (within the stomach pouch) surface averages about 20 μ high, while that on the subumbrellar surface (lining the bell cavity) averages about 35 μ high. On each surface the margins of the cells are difficult to define, and the cell nuclei give the appearance of being suspended in a layer between the basal and free membranes by a series of basophilic cobwebby fibres, which enclose many vacuoles in a reticular structure. The nuclei tend to be elongated, with their long axes parallel to the cell height. On the subumbrellar side the cells are more delicate, and the nuclei are nearer the surface.

The subumbrella thus consists of (from the outside in): firstly, the layer of cells described within the stomach pouches, then a layer of mesogloea 25 μ thick, then a layer of circular muscle averaging about 30 μ thick, and finally a layer of columnar cells, about 35 μ high, which are the lining cells of the bell cavity. They are similar to the epithelial cells on the other side of the subumbrella, but the layer appears denser and the strands of cytoplasm thicker. The nuclei are irregular, apparently suspended in a layer about one-third of the distance down from the apex. The cytoplasm is granular, non-vacuolated on the apical side of the nucleus; on the basal side of the nucleus the cytoplasm appears foamy from the presence of many vacuoles.

At the very edge of the stomach pouch, over the last 10-20 μ alongside the interradial septum, the epithelial cells become shorter. The two layers (i.e. on the axial and abaxial sides of the pouch) may meet without complication, or they may be reflected into a narrow ridge or lamina, which is termed the "lateral gonad" in this species, on the grounds of its analogous position to that of the gonad in *Chiropsalmus* (e.g. *C. quadrumanus*). In *Chironex fleckeri*, however, this structure does not present the typical histological appearance of gonads in the Cubomedusae. In section the "lateral gonad" may present in one stomach pouch as a pyriform structure 215 μ long by 80 μ across, or on the other side of the interradius as a sausage-like structure, 390 μ long by 40 μ across (Plate 1, Fig. 5). The outer part of the "lateral gonad" is composed of the same types of cells as in the adjacent epithelium of the stomach pouch. Penetrating a little way into the core of the "lateral gonad" is a lamina of mesogloea which evidently corresponds to the axial plate. Strands attach to this from the superficial cells. Within the interstices of these strands are a number of cells with larger nuclei (nuclei up to 5 μ across) with a more definite layer of cytoplasm. The whole appearance of the structure resembles only obscurely that of the superior gonad of *Chironex fleckeri*.

In one specimen depicted (Plate 1, Fig. 4) a more primitive structure exists, consisting of a compressed collection of cells 60 μ long by 15 μ across, with no sign of a mesogloeal axial lamina. On the other side of the interradius in this specimen the structure is entirely absent. In the immature specimen examined histologically

(Plate 1, Fig. 3; from specimen S. A. M. H18) no trace of the "lateral gonad" can be seen with any certainty in this admittedly rather poorly fixed specimen. Further studies must await the examination of material better fixed for histological purposes.

IV. Discussion on the Cubomedusae from Tropical Australian and Adjacent Waters

Sufficient has been said above to distinguish *Chironex fleckeri* from *Chiropsalmus quadrigatus* Haeckel, 1879 (as redescribed by Mayer in 1910 from Philippine material), the best known of the larger Cubomedusae from the Pacific and Indian Oceans. Apart from the differences recorded in the system of the lateral and possibly superior gonads, *Chironex fleckeri* appears to have, in specimens of comparable size, a greater number of pedalial claws and tentacles. Nevertheless the recording of so large a medusa as new is rather surprising, and its possible relationship to previously described forms should be examined carefully. Lesson (1830) was the first to describe such medusae from the Pacific Ocean, and possibly the forms represented by him belonged to *Tamoya*, in which the pedalium carries a single tentacle. A discussion on these will be found in Bigelow (1938, pp. 150-1). Uchida (1947) has further discussed the distribution of the Pacific Cubomedusae of the genera *Carybdea* and *Tamoya*. He recorded (loc. cit.) two cubomedusan specimens "obtained by Mr. S. Wada off the River Liverpool, Arnhem Land, Northern Australia". Both specimens were approximately 30 mm high and 22 mm wide, and were referred to *Tamoya bursaria* Haeckel.

Haeckel (1879) described *Chiropsalmus quadrigatus* from what was apparently a juvenile specimen, from the Indian Ocean off Rangoon, collected in 1863. Mayer (1910) gave an account of a large Philippine Cubomedusa which he referred to the same species, which has been mentioned above. It may be stated that uncertainty attaches to the identification of Cubomedusae based on immature forms. Light (1921) recorded *C. quadrigatus* as common in the Philippines ("except in inclosed bays").

An immature Cubomedusa, *Procharybdis flagellata*, was described by Haeckel (1879, p. 438), its name being based on *Marsupialis flagellata* Lesson, 1843. Haeckel gives the following locality information "Nordküste von Australien; Torres-Strasse, Weber (Neu-Guinea, Lesson?)". Von Lendenfeld (1885) repeated Haeckel's account. Mayer (1910) stated that Haeckel's *P. flagellata* was "too inadequately known to be profitably retained in scientific literature".

Thiel (1928) described *Chiromedusa debrachiata* as a new genus and species of Cubomedusa, from two specimens captured at "Luschan-Hafen, Neu Pommern" (New Britain). In the type specimen the bell measured approximately 5 cm high by 4 cm broad. With regard to the gonad this author stated (loc. cit., p. 11): "In den Ecken dieser (Gastral-) Taschen befinden sich die Geschlechtsorgane (Abb. 1G), die als grosse in der Mitte sehr breite, dann nach oben und unten schmälere und dann wieder breitere Lappen in den Interradien festgewachsen sind und, etwas in sich gefaltet frei in die Gastralhöhle hineinhängen"—a male. In the same paper Thiel described some features of Haeckel's type specimen of *Chiropsalmus quadrigatus*, in the Copenhagen Museum. Thiel's (1928) Figure 6*b* shows (diagrammatically) a section through the bell of that specimen. A small mammillary process on the inner side of the bell (*A* in the diagram) is labelled "Taschenarm". It was on the lack of this structure that Thiel separated off his genus *Chiromedusa.* It is, however, probable that the structure labelled *A* by Thiel was part of the immature "gastric saccule" or "superior gonad". Thiel (1936) referred again to his New Britain specimens, and synonymized them with *C. quadrigatus* Haeckel. It may therefore be concluded that whatever the relationship of *Chiromedusa* may be to other Cubomedusae, from the structure of its lateral gonad it cannot be the same as *Chironex.*

One further genus has been erected for a medium-sized Cubomedusa found in northern Australian and adjacent waters. This was described from Java by Horst (1907) as *Chiropsalmus buitendijki.* In this rather anomalous form the branches of the pedalium (claws) form a linear series, unlike any other Cubomedusa. Krumbach (1925) made this form into a separate genus, *Drepanochirus*, and divided the Cubomedusae into the families Carybdeidae, Drepanochiridae, and Chirodropidae. As, however, the genus *Drepanochirus* is preoccupied by Péringuey (1901) for a coleopterid, a new name is necessary for Krumbach's genus. The genus *Chiropsoides*, nom. nov. pro *Drepanochirus* Krumbach, 1925, non Péringuey, 1901, is proposed here. It is necessary to replace Krumbach's family Drepanochiridae with Chiropsoididae, nom. nov. (assuming that that family is to survive). This genus and family has but a single species, *C. buitendijki*, comb. nov. This species is well known along the Madras coast of India (Menon 1930), and has been recorded also from Krusadai Island (between India and Ceylon) (Menon 1936) as well as from Indo-Chinese waters (Dawydoff 1936). Stiasny (1926) recorded two specimens taken at Bowen Harbour, Qld., stranded after a gale, as belonging to this species. These, though damaged, were stated as being immediately recognizable from the arrangement of the tentacles. One is rather more inclined to doubt the identification by the same author (loc. cit.) of a juvenile and badly damaged Cubomedusa from Port Darwin, N.T., as *Chiropsalmus quadrumanus* (Müller). The only other identification of this species, apart from the Atlantic Ocean, is that of Rao (1932), who recorded four specimens from Indian waters.

V. The Systematics of the Order Cubomedusae

It is proposed to re-examine the systematics of the Cubomedusae in the light of the presence of the two systems of gonads described within the group. It is clear that this difference is of some importance. The systematics of the Cubomedusae have been a problem of considerable difficulty to past workers. This is reflected in the fact that in the past practically every genus of this group has had a family founded upon it. In some of the more recent classifications the group has been restricted to two families thus (Uchida 1929; Bigelow 1938):

Cubomedusae with 4 simple or tripartite interradial tentacles with pedalia; without diverticula of the 4 stomach pockets ....Carybdeidae Haeckel, 1879
Cubomedusae with 4 interradial tentacle clusters, with 8 diverticula (Umbralsäcke) of the 4 stomach pockets ....Chirodropidae Haeckel, 1879

On the other hand other families have been proposed. Thus Conant (1897) set up the family Tripedaliidae, which some later authors have included in the

Carybdeidae. Thiel (1936) synonomized *Chirodropus* Haeckel, 1879, with *Chiropsalmus* L. Agassiz, 1862—a quite unjustifiable procedure in the present writer's opinion, in view of the marked differences in the gonads—and replaced Chirodropidae Haeckel, 1879, with Chiropsalmidae Thiel, 1936.

Although one would wish to know more of the histological structure of the "superior gonad" in *Chiropsalmus quadrumanus* (Müller) and *C. quadrigatus* Haeckel, 1879 (Mayer 1910), and of the structure of *Chiropsoides buitendijki* (Horst 1907), yet there appears no doubt that between *Chironex* and some other Cubomedusae at least there is a different system of gonads. Only in the genera *Chironex* and *Chiropsalmus* have the "superior gonads" been observed. In *Chiropsalmus zygonema* Haeckel, 1879, the author recorded (p. 641) "Die beiden Taschen-Arme an der Umbral-Wand jeder Radial-Tasche, nahe deren Eingang, eiförmig, sehr klein". Unfortunately Haeckel does not figure this species. The sentence quoted could be a description of a small "superior gonad", but it cannot be interpreted with certainty. Probably *C. zygonema* is an immature form. The bell was 60 mm high and 40 mm wide. Each pedalium was provided with two long tentacles.

In the case of the genus *Chirodropus* Haeckel, 1879, the genotype *C. gorilla* Haeckel, 1879 (from West Africa), has been described and figured in detail. There appears no evidence of a "superior gonad", and apart from the grape-like clusters along the edge of the gonads, the gonads appear normal for the Cubomedusae. Haeckel stated that: "Die 8 Gonaden . . . füllen den grössten Theil der lateralen Räume der Radial-Taschen aus", which is confirmed by careful examination of his figure.

In *Chiropsoides*, nom. nov., the structure is unusual in the large bellying diverticula ("Umbralsäcke") of the gastrovascular spaces, which encroach on the bell cavity. Examination of the description by Horst (1907), and of the figures of Horst (loc. cit.) and Krumbach (1925), shows no evidence of a "superior gonad".

Since both male and female gonads have been observed in both the lateral and superior positions in the Cubomedusae, it would appear unlikely that any one form of Cubomedusa should have two systems of functioning gonads.

Since normally in the Scyphozoa the sexual cells are discharged into the coelenteric cavity, it would possibly appear best to regard the superior gonad in *Chironex* as developing within a detached part of the coelenteric space. There appears little reason to doubt that in *Chironex* the sexual products are discharged into the bell cavity, presumably by the breakdown of the external limiting membrane of the gonad.

At present the writer is hesitant to set groups of higher than family status within the Cubomedusae, until more is known of the structure and embryology of the gonads in various members, e.g. those mentioned above. For the present it would appear best to restrict systematic alterations to that of erecting a new family Chironecidae, based on *Chironex*, and containing that one genus. The Cubomedusae could then be classified into three families: the Carybdeidae and Chirodropidae as in the classification of Uchida and Bigelow above, with the following addition:

The gonad a paired structure, consisting of 2 hemigonads arising alongside the perradial suspensoria, high in the bell cavity, and projecting into the bell cavity. The lateral gonad, originating at the interradius within the perradial stomach pouches, an insignificant and possibly functionless structure (definition) ......Chironecidae, fam. nov.

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Explanation of Plates 1-3

Plate 1

Chironex fleckeri, gen. nov., sp. nov. Sections stained with Harris's haemalum and counter-stained with 0·1 per cent. alcoholic eosin. Figs. 3-5 are further described in text

Fig. 1.—Transverse section of adult tentacle.

Fig. 2.—Longitudinal section of same, to same scale as Fig. 1.

Fig. 3.—Transverse (horizontal) section of the interradial septum of an immature specimen (S. A. M. H18). The epithelium of the subumbrella surface (uppermost in the photograph) has been lost. The epithelium of the stomach pouches has become detached over some of the area shown. There is no sign of a lateral gonad.

Fig. 4.—Transverse (horizontal) section of the interradial septum in a mature specimen, similarly orientated.

Fig. 5.—Section of same region in another adult, similarly orientated, showing a more marked "lateral gonad".

Plate 2

All sections stained and counterstained as in Plate 1

Fig. 1.—*Chironex fleckeri*. Section of pinnate gland.

Fig. 2.—*Chiropsalmus quadrumanus* (Müller). Section of the lateral gonad, a ripe testis, in a mature specimen.

Fig. 3.—*Chironex fleckeri*. Section of testis, showing the external limiting membrane (the 3 replicated thin layers on the left), and the replicated testicular layer (on the right).

Fig. 4.—Further enlargement of the testicular layer in *C. fleckeri*. Three folds are shown cut. See text for further description.

Plate 3

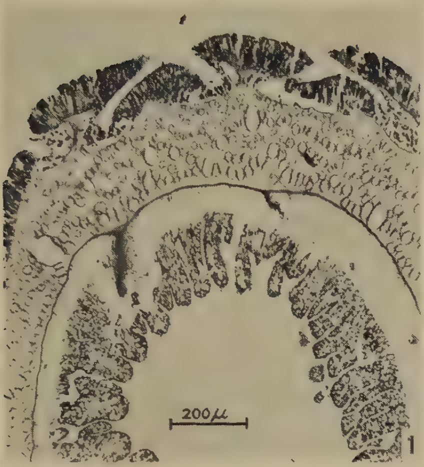
Chironex fleckeri. All sections except Fig. 4 stained and counterstained as in Plate 1

Fig. 1.—Section through the superior gonad (ovary) of a nearly mature female (specimen from Cardwell). The photograph shows two projections (above and below) of the mesogloeal core with its adherent internal epithelium, each being crumpled and distorted by fixation. Adjacent is the replicated ovarian layer. Projecting in from the right in the middle of the photograph is a fold of the external limiting membrane.

Fig. 2.—Same specimen, showing further enlargement of the ovarian layer; see text.

Fig. 3.—Section of the superior gonad (ovary) of the mature Darwin female, showing the ripe ovarian layer, with the external limiting membrane.

Fig. 4.—Further enlargement of the ovarian layer, stained with Weigert's iron haematoxylin without counterstaining, showing ripe ova within the remains of the axial plate, and yolk spherules (see text).



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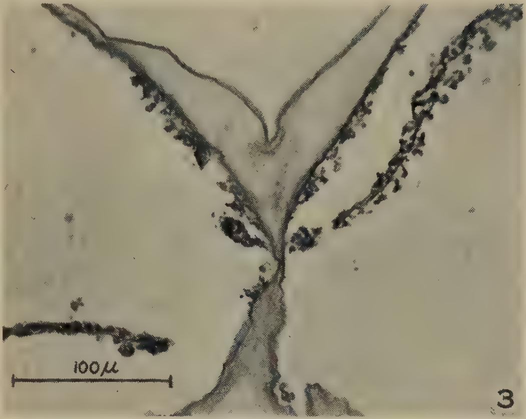

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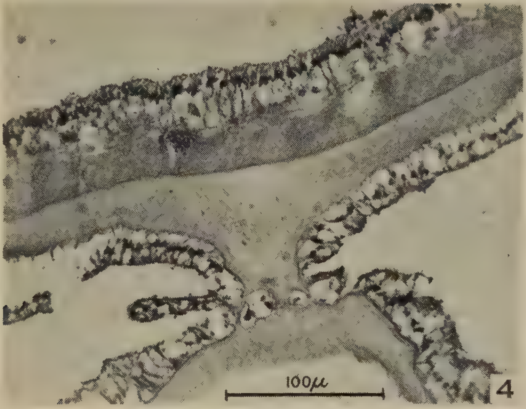

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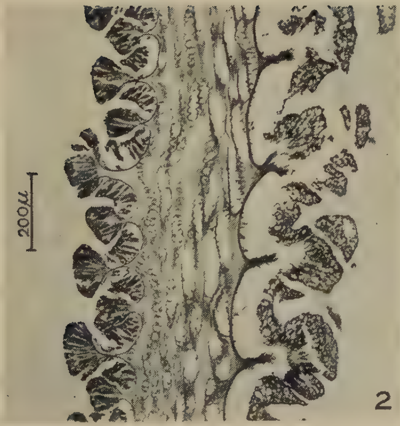

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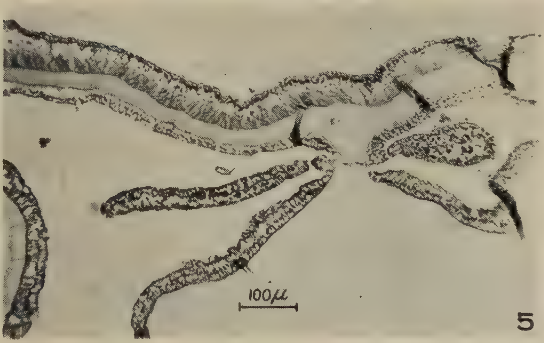

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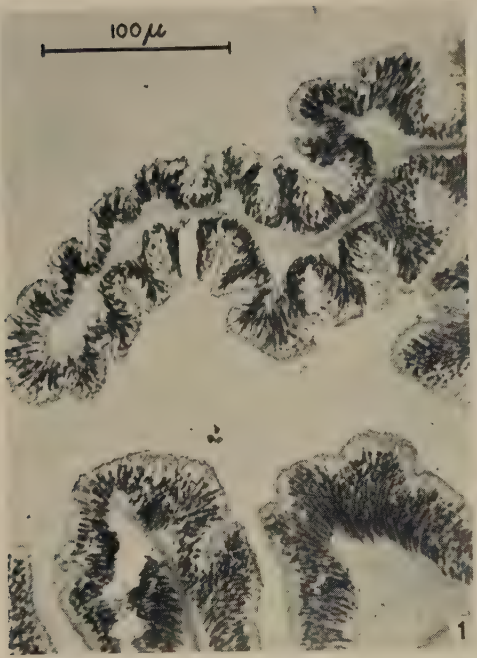
AUSTRALIAN CUBOMEDUSAE



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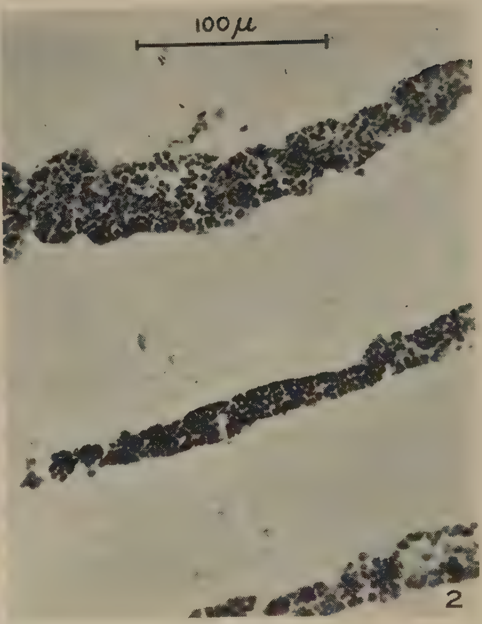

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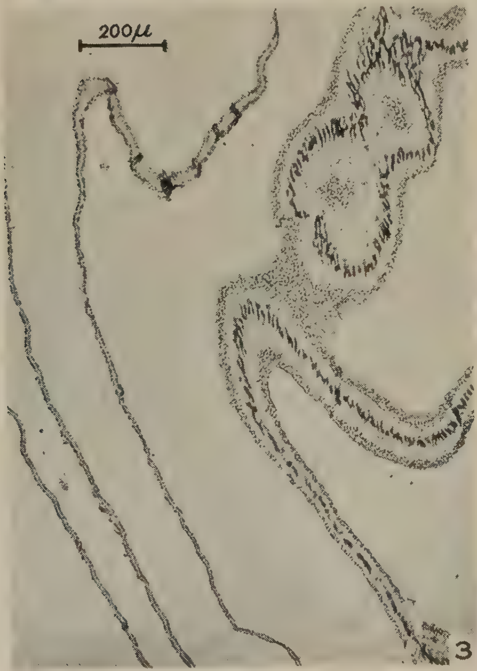

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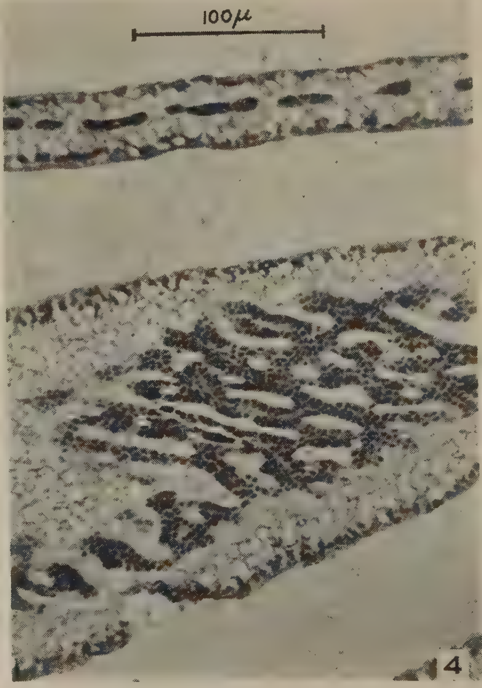

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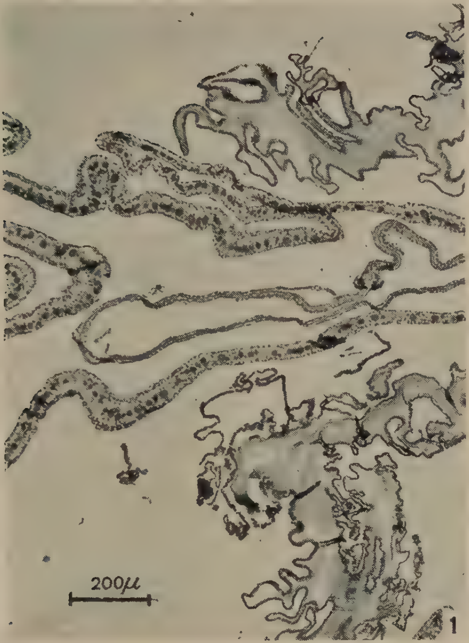
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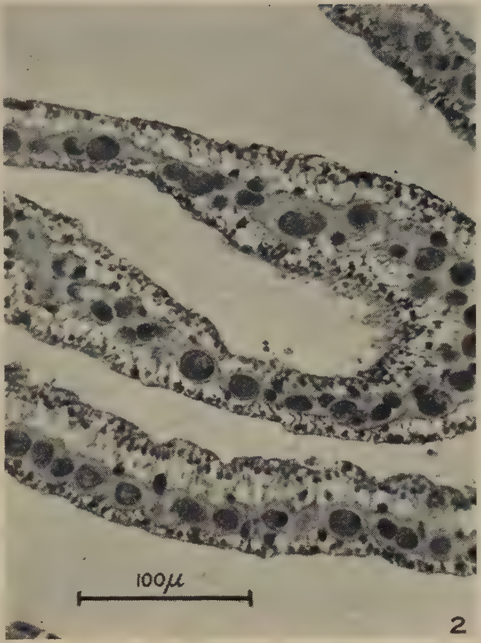
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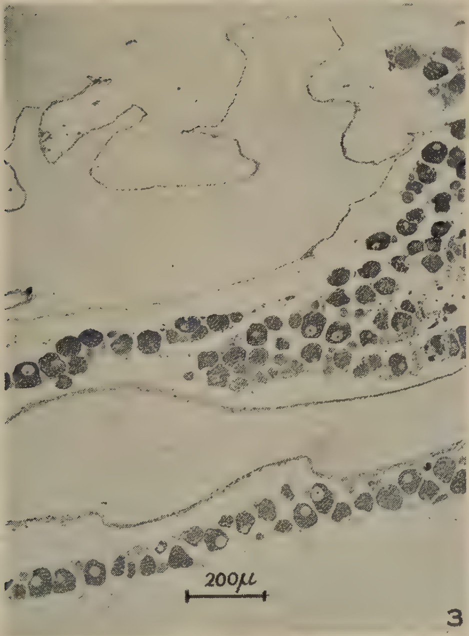
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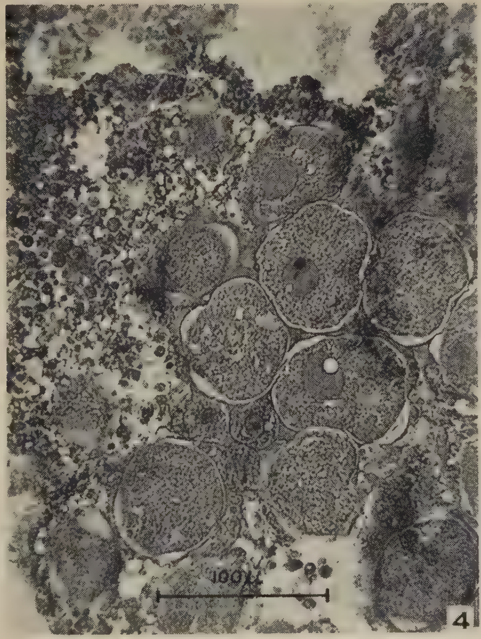
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AUSTRALIAN SIPUNCULOIDEA

II. THE GENERA PHASCOLOSOMA, DENDROSTOMUM, GOLFINGIA, ASPIDOSIPHON, AND CLEOSIPHON

By S. J. Edmonds*

[*Manuscript received December* 19, 1955]

Summary

This paper deals with the following genera of Australian sipunculids: *Phascolosoma, Dendrostomum, Golfingia, Aspidosiphon,* and *Cleosiphon.* Nineteen species are recorded, of which *Phascolosoma rottnesti* from Western Australia, *Phascolosoma dunwichi* and *Phascolosoma heronis* from Queensland, and *Dendrostomum cymodoceae* from South Australia are new. *Phascolosoma scolops* var. *tasmaniense* has been given specific rank as *P. tasmaniense.* Two new subspecies, *Golfingia margaritacea adelaidensis* from South Australia and *G. vulgaris queenslandensis* from Queensland, are also described. A key to the Australian genera and species is given.

Description of Genera and Species

Genus PHASCOLOSOMA Leuckart

Phascolosoma Leuckart, 1828, p. 22. Fisher, 1950, p. 551.
Physcosoma Selenka & de Man, in Selenka, de Man, and Bülow, 1883, p. 54.

Diagnosis

Longitudinal musculature divided into separate bundles which may anastomose considerably. Usually 4 retractor muscles, the dorsal and ventral on each side tending to fuse in some species. Body covered with papillae which bear small chitinous platelets. Introvert hooks usually present and arranged in rings. A dorsal contractile vessel, usually without villi, runs along the oesophagus. Tentacles arranged in a single crescent or a circle dorsal to the mouth.

Type, *Phascolosoma granulatum* Leuckart.

Remarks.—This genus was formerly but incorrectly called *Physcosoma.* Fisher (1950) has shown that the name *Phascolosoma* has priority over *Physcosoma* and in his last papers Fisher used the term *Phascolosoma* in place of *Physcosoma.* Fisher's nomenclature, adopted recently by Wesenberg-Lund (1954*a*, 1954*b*), is used in the present paper. The synonomy of *Phascolosoma*, *Phymosomum*, *Physcosoma*, etc. is given by Fisher in his paper on the Californian sipunculids (Fisher 1952, p. 422).

Specimens belonging to this genus have been collected from the intertidal regions of eastern, southern, and Western Australia. None, unfortunately, are at hand from northern Australia. Most of the species bear strong anatomical resemblances to each other and are closely related. They are separated into species chiefly on the differences between the structure of their hooks and papillae. It may be worth while pointing out that all the previous Australian records of *P. agassizi*, *P. scolops*, and *P. japonicum* have been placed in this paper in the synonomy lists of other, usually new, species.

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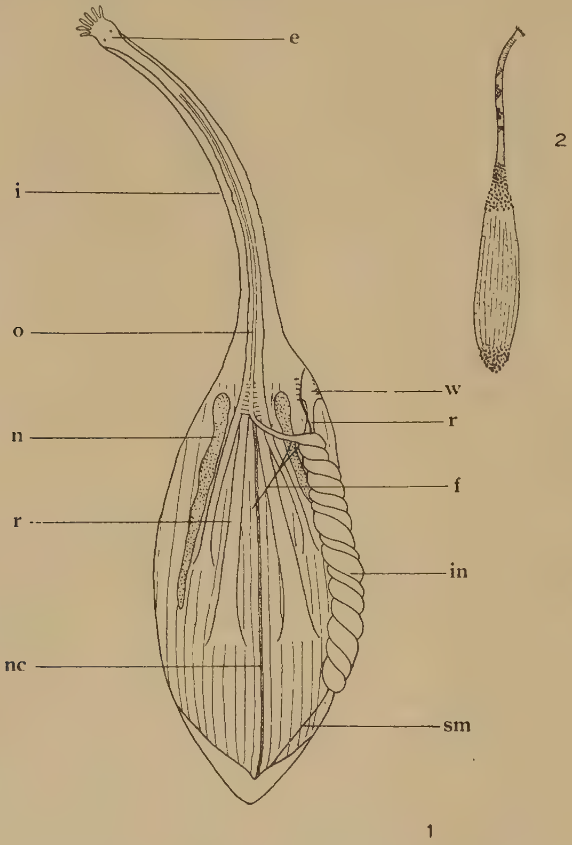
* Department of Zoology, University of Adelaide.

PHASCOLOSOMA ROTTNESTI, sp. nov.

Figs. 1-4

Physcosoma agassizi Fischer, 1919, p. 277. Fischer, 1926, p. 200.

Specimens examined, 83 (8 dissected).—WESTERN AUSTRALIA: Garden I., on lip of swimming reef, Mrs. L. Marsh (Univ. of W.A.); Rottnest I., 8.xi.1954, "embedded in calcareous rock platform", Dr. Hodgkins (Univ. of W.A.); Port Dennison (specimens from Univ. of W.A.).

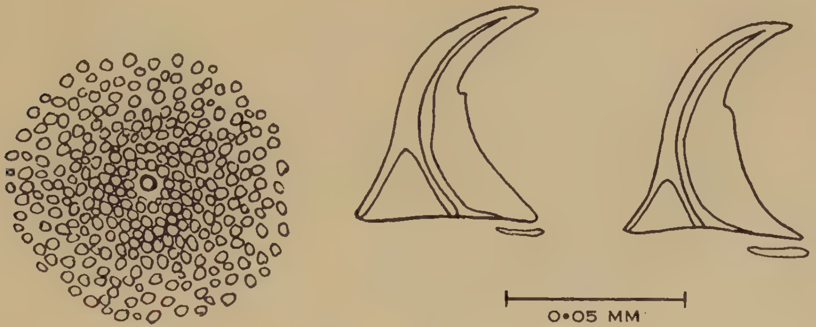


Figs. 1-2.—*Phascolosoma rottnesti*. Fig. 1.—Dissected specimen. *e*, eyespot; *f*, fastener; *i*, introvert; *in*, intestine; *ir*, introvert retractor; *n*, nephridium; *nc*, nerve cord; *r*, rectum; *sm*, spindle muscle; *w*, wing muscle. Fig. 2.—Entire animal.

Description

The length of the trunk of the specimens is 1·5–3·3 cm and the maximum width 4-5 mm in the posterior half of the trunk. The introvert when fully extended is about as long as the trunk and its width 1·5–2 mm. Freshly preserved specimens are straw, pale brown, or pinkish brown in colour except at the anterior and posterior regions of the body which are dark brown. Pigmented bands, varying in number and width, appear on the dorsal surface of the introvert. In some specimens they surround the introvert. There are 15-20 finger-like tentacles which lie dorsal to the mouth. From 15 to 34 rows of small light brown or dark brown hooks are present on the introvert anteriorly. Some of them are shown in Figure 4. In most specimens the clear streak or channel which runs through the centre of the hook is swollen near its middle.

The surface of the animal bears numerous papillae which vary considerably in size and shape. Those between the rows of hooks are very small and form complete transverse rings. Towards the base of the introvert they gradually become larger, more pointed or conical, and darker in colour. Those on the anterior region of the body are larger, circular in outline, densely packed, less conical in shape, and dark brown in colour. Their diameter is 0·2–0·4 mm. The papillae on the remainder of the trunk, except the posterior region, are smaller, rounded, more scattered, and less noticeable. Those at the posterior region of the trunk are large (0·2–0·45 mm in diameter), densely packed, and dark brown. The surface of the papillae is covered with numerous, small chitinous plates of almost uniform size (Fig. 3).



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Figs. 3-4.—*P. rottnesti.* Fig. 3.—Papilla from posterior surface of trunk. Fig. 4.—Introvert hooks.

The longitudinal musculature of the body wall is divided into 19-24 anastomosing bundles which are usually visible externally. Four retractor muscles are present. Two stout ventral retractors arise in the posterior half of the trunk from muscles 2-5 (2-6, 2-7) and 2 more slender dorsal retractors more anteriorly from muscles 4-6 (5-6, 5-7).

The fore region of the oesophagus is attached to the dorsal retractors by thin mesenteries. The intestinal coils are held firm by a stout spindle muscle which arises anteriorly near the anus and which is fixed posteriorly to the body wall. In some specimens the spindle muscle is fused for a short part of its length with the rectum. A fastening muscle arises from muscle 1 in the left side of the nerve cord at about the level of the dorsal retractor. In some specimens it is attached to the last whorl of the intestine. In others it bifurcates, in which case one root is fixed to the oesophagus near its junction with the intestine and the other root to the last whorl of the intestine.

The length of the nephridia is about half to two-thirds that of the trunk. The nephridia open to the exterior between muscles 2-3 or 3-4 and are attached to the body wall for about one-third to half their length. There is a poorly developed dorsal contractile vessel and 2 small eyespots are present near the brain. There is a small intestinal caecum. Ripe eggs, about 0·1 mm in diameter, were found in specimens collected from Rottnest I. in November.

Systematic position

These specimens closely resemble *P. agassizi* Keferstein and *P. scolops* (Selenka & de Man) and are most likely similar to those from Shark Bay and Rottnest I., W.A., identified as *P. agassizi* by Fischer (1926, p. 200). *P. agassizi*, described from California, and *P. scolops*, described from the Philippines, Singapore, and the Red Sea, are troublesome species. Wilhelm Fischer (1922, p. 7) says that *P. agassizi* occurs in all tropical and temperate seas, but W. K. Fisher (1952, p. 430) after making a very careful examination of a large number of specimens from the Pacific coast of North America inclines to the view that it is a cold-water form confined to Alaska and California.

The hooks of the Western Australian specimens, especially those in which the clear streak is swollen near its middle, are very close to some of those of *P. agassizi* as shown in Plates 37 and 38 of Fisher (1952). The clear streak of the Western Australian specimens is, on the other hand, wider at its base than those shown by Fisher and in this respect resembles more that for *P. scolops* shown in Figures 139 and 144 of Selenka's monograph (Selenka, de Man, and Bülow 1883). On the basis of the structure of the hooks these specimens could possibly be regarded as subspecies of either *P. agassizi* or *P. scolops*.

The papillae of the Western Australian specimens are noticeably different, however, from those of *P. agassizi* and *P. scolops*. They consist of numerous small, chitinous platelets of approximately equal size (Fig. 3). There is no ring of larger plates around the glandular opening of the papillae as shown for *P. agassizi*, both by Fischer (1922, Fig. 4) and Fisher (1952, Plate 36, Fig. 3), and for *P. scolops* by Selenka (Selenka, de Man, and Bülow 1883, Fig. 143). This difference in the structure of the papillae of the Western Australian and Californian specimens is shown also in Figures 3 and 4 of Fischer (1922). It is for this reason then that the specimens from Western Australia are being regarded as new.

The Western Australian specimens have been compared with six specimens of *P. agassizi* from Monterey Bay, California, kindly forwarded by the late W. K. Fisher. The papillae of the two lots of specimens differ not only in structure but also in their distribution. The papillae of the Western Australian specimens are more densely packed on the anterior and posterior extremities of the trunk than in *P. agassizi*. The Western Australian sipunculids differ from *P. scolops*: (i) in the structure of the papillae; (ii) in possessing a rectal caecum, a structure not mentioned by Selenka in his description of the species and not present in Japanese specimens (Sato 1930, p. 13) nor in Malayan specimens (Wesenberg-Lund 1937, p. 9).

P. rottnesti is a new species allied anatomically to *P. agassizi* and *P. scolops*. differing from each and all other Australian species of the same genus in the structure of its hooks and papillae.

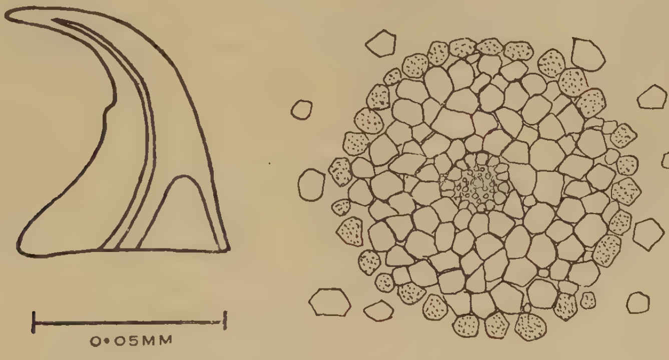
Type locality.—Rottnest I. (near Fremantle), W.A.
Type specimen.—Australian Museum, Sydney.
Distribution.—Western Australia.

PHASCOLOSOMA TASMANIENSE (Fischer)

Figs. 5-6

Physcosoma scolops var. *mossambicense* Augener, 1903, p. 339.
Physcosoma scolops var. *tasmaniense* Fischer, 1914, p. 3.
Physcosoma scolops Wheeler, 1938, p. 346.

Specimens examined, 103 (10 dissected).—TASMANIA: Lighthouse Point, Cockle Bank, South Tas., 3.xii.1953, "under stones at low-tide", Prof. V. Hickman (Univ. of Tas.) (5 spec.). VICTORIA: Shoreham (Univ. of Melb.) (4 spec.). SOUTH AUSTRALIA: Vivonne Bay, Kangaroo I., "embedded in thick mass of tubes of the serpulid worm, *Galeolaria*", 8.i.1949; Emu Bay, Kangaroo I., 16.ii.1948, "under stones at low water"; Venus Bay on Eyre Peninsula, "in thick mass of tubes of *Galeolaria*", 5.ii.1954; Scott's Bay, near Fowler's Bay, "very numerous, boring in a calcareous rock platform", 12.ii.1954 (all specimens (94) from S.A. collected by S. J. Edmonds).



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Figs. 5-6.—*Phascolosoma tasmaniense*. Fig. 5.—Introvert hook. Fig. 6. Papilla from posterior surface of trunk.

Description

The length of the trunk of the specimens is 2·5-4·1 cm and the maximum width in the posterior half is 5-7 mm. The introvert is almost as long as the trunk and bears 20-26 finger-like tentacles and at least 15 complete and a number of incomplete rows of dark coloured hooks. The structure and size of some of the hooks are shown in Figure 5. They resemble those of *P. scolops* and *P. agassizi*. The clear streak which runs down the centre of the hook in both species is much finer in *P. tasmaniense* and the clear triangular area is not as well marked as in *P. scolops*.

The specimens are brown in colour, the anterior and posterior regions being very dark brown. The papillae at the base of the introvert are large, conical, and closely packed, especially on the dorsal surface. In the mid body region they are smaller and more scattered. They are largest (0·2-0·4 mm in diameter) at the posterior body region, more densely packed, and flatter. The papillae are made up of comparatively large polygonal plates closely set together (Fig. 6). At the base of each papilla there is an almost complete ring or row of darker plates. Brownish yellow platelets are scattered over the surface of the body between the papillae. They appear to be detached plates of the papillae but are, however, firmly attached to the body wall and found in all specimens. They are shown in Figure 4 of Fischer's description of *P. scolops* var. *tasmaniense*. A number of pigmented bands, some incomplete, are found on the dorsal side of the introvert.

There are 18-22 anastomosing longitudinal muscles usually visible externally. A pair of stout ventral retractors arise in the posterior half of the body from muscles 2-6 (2-5, 2-7, 3-6) and a pair of more slender dorsal retractors more anteriorly from muscles 5-6 (4-6, 5-7). A spindle muscle is fastened anteriorly near the anus and posteriorly to the body wall. Wing muscles are attached to the rectum near the anus. A fastening muscle arises from muscle 1 near the left dorsal retractor and joins the last whorl of the intestine. In some cases the fastener bifurcates. The nephridia arise at about the same level as the anus and are about half as long as the body. A poorly developed contractile vessel is present but no intestinal caecum was found. Ripe eggs, from specimens collected in January, are about 0·1 mm in diameter.

Systematic position

This species differs from *P. scolops* in three respects: (*a*) most noticeably, in the structure of the papillae which are composed of large plates, resembling those of *P. japonicum* as shown in Figure 29 of Sato (1939); (*b*) in the presence of scattered platelets on the trunk; (*c*) in the structure of the hook, in which the clear central channel is narrower and the clear triangular region less obvious than in *P. scolops*.

As these differences occur constantly in material collected along a considerable length of coastline, the specimens are considered to be new. *P. tasmaniense* is readily distinguishable from other Australian members of the same genus by the structure of its papillae. It is probable that *P. scolops* from Sir Joseph Banks Is., Spencer Gulf, S.A. (Wheeler 1938), is also *P. tasmaniense* and possibly *P. scolops* from "off Tasmania" (Benham 1922). Two specimens have been deposited in the Australian Museum, Sydney.

Distribution.—South Australia, Victoria, and Tasmania.

PHASCOLOSOMA NODULIFERUM Stimpson

Figs. 7-8

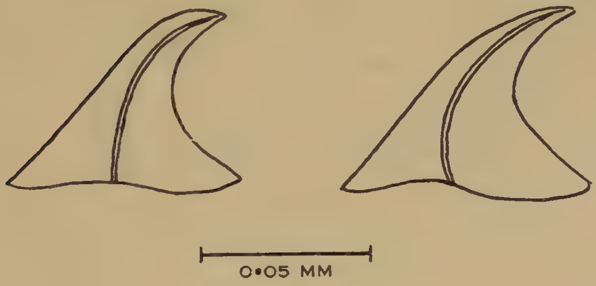
Phascolosoma noduliferum Stimpson, 1855, p. 390. Keferstein, 1865*b*, p. 423.

Physcosoma japonicum Selenka & de Man, in Selenka, de Man, and Bülow, 1883, p. 76 (in part).

Specimens examined, 38 (6 dissected).—NEW SOUTH WALES (22): Long Reef, near Port Jackson, Jan. 1948, Miss E. Pope (Aust. Mus.); Harbord, Miss I. Bennett (Univ. of Syd.). VICTORIA (12): San Remo, Prof. O. Tiegs (Univ. of Melb.); The Nobbies, Phillip I., May 1947 (Nat. Mus., Melb.). TASMANIA (4): Eaglehawk Neck, Prof. V. Hickman (Univ. of Tas.).

Description

The length of the trunk is 2·3-5·0 cm and the maximum width in the posterior half of the trunk is 8-12 mm. Living specimens are light brown to buff coloured, with only a slight darkening at the anterior and posterior regions of the trunk. Superficially the specimens closely resemble the specimen of *P. japonicum* shown in Selenka's monograph (Selenka, de Man, and Bülow 1883, Plate 2, Fig. 19). The introvert is about as long as the body and lacks the darkly pigmented bands found in a number of allied species, e.g. *P. rottnesti*, *P. tasmaniense*, and *P. dunwichi*. It bears about 20-24 tentacles and a varying number of rows of dark brown hooks. The greatest number of rows observed in any specimen was 25 complete and 46 partial rows. The size and structure of some of the hooks are shown in Figure 7. The characteristics of the hooks are a broad base, a thin, clear streak, and a uniform dark brown colour.



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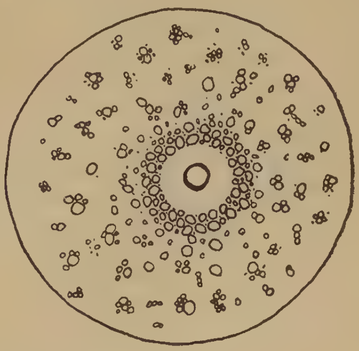

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Figs. 7-8.—*Phascolosoma noduliferum.* Fig. 7.—Introvert hooks. Fig. 8.—Papilla from posterior surface of trunk.

The introvert and the trunk bear rather large, rounded papillae, a little darker than the rest of the body wall. The papillae are largest and densest on the anterior and posterior body surfaces. There is not such a marked difference in size between these papillae and those of the mid body region as is encountered in other Australian species of the same genus. The papillae, the largest of which range from 0·3-0·45 mm in diameter, consist of numerous small plates and scattered granules (Fig. 8).

The body wall is thick so that the longitudinal bands of muscle are not always apparent externally. In preserved, contracted specimens the body wall often is wrinkled by transverse ridges. When the animal is dissected, about 20-26 longitudinal muscles which anastomose considerably are seen. There are 4 retractor muscles. One pair of stout ventral retractors arises from muscles 2-6 (2-7, 1-6) in the posterior half of the trunk and a second pair of more slender dorsal retractors arises more anteriorly from muscles 5-7 (5-6, 6-7). The dorsal and ventral retractors on each side fuse in the anterior oesophageal region. The oesophagus is fixed to the retractors by 2 thin mesenteries and the intestine consists of about 10-15 whorls. In some specimens the coils nearest the posterior extremity of the body are light green in colour. A spindle muscle is fixed anteriorly near the anus and posteriorly to the body wall. There are two well-developed wing muscles. A fastening muscle arises from muscle 1 or 2 near the left ventral retractor. The nephridia are about half as long as the trunk and open externally between muscles 2-3 or 3-4. In some specimens they are expanded near the nephrostome. They are fixed for about three-quarters of their length. There is a dorsal contractile vessel but no intestinal caecum could be found. Ripe eggs are about 0·12 mm in diameter.

Systematic position

Stimpson (1855, p. 390) described a single sipunculid collected from "under stones" at Port Jackson, N.S.W., as *Phascolosoma noduliferum.* Stimpson's description, however, by modern standards is rather inadequate. Keferstein (1865*b*, p. 423) examined presumably the same specimen and redescribed it. Keferstein's figures of the internal anatomy (Tafel xxxii; Fig. 16) and especially of the structure of the introvert hook (Fig. 17) make it clear, in the opinion of the present writer, that the sipunculids from Long Reef, Harbord, San Remo, etc. are *P. noduliferum.*

P. noduliferum has for some time been regarded in New South Wales as *P. japonicum* (see Whitelegge 1889, p. 211; Dakin 1952, p. 157, and Plate 33, Fig. 6). This follows as a result of the identification of two sipunculids from New South Wales as *P. japonicum* by Selenka (Selenka, de Man, and Bülow 1883, p. 77). Although the two species superficially resemble each other they differ noticeably in two respects, the structure and shape of the introvert hooks and the structure of the papillae. The hooks of the specimens from New South Wales have: (i) a relatively broad base; (ii) a characteristic narrowing towards the apex, a feature shown neither in Selenka's drawings (Selenka, de Man, and Bülow 1883, Fig. 145) nor in Sato's figures of *P. japonicum* (Sato 1930, Fig. 2). The papillae are also different from those of *P. japonicum.* In the latter species the papillae consist of large polygonal plates and are bordered with a row of darker plates. In *P. noduliferum* the plates are very small and no pigmented row is present. An examination of a specimen of *P. japonicum* from Aikawa, Rikuzen, Japan, has confirmed the fact that the Australian and Japanese forms are distinct. The specimen was made available for study by the late W. K. Fisher and is one of two referred to by Fisher (Fisher 1952, p. 429). Both the hooks and papillae of this specimen correspond with those of *P. japonicum* as shown by Selenka (Selenka, de Man, and Bülow 1883) and Sato (1930, 1939). *P. japonicum* has been reported from Port Jackson by Selenka (Selenka, de Man, and Bülow 1883) and Fischer (1922). The specimens identified by Selenka are in the British Museum of Natural History, London, and have been re-examined by the present author. They are registered as 85.12.3.30 and 85.11.3.30. The hooks and papillae of these two specimens are those of *P. noduliferum* and not *P. japonicum.* The possibility of these specimens being *P. noduliferum* occurred to Selenka, because he says (Selenka, de Man, and Bülow 1883, p. 77): "Vielleicht ist diese Species identisch mit dem *P. noduliferum* Stimpson; da wir aber das Stimpson'sche Original examplare nicht untersuchen konnten, behalten wir vorläufig den Grube'schen Namen bei".

P. noduliferum differs from allied species in the structure of its hooks and papillae. No pigmented bands are found on its introvert.

PHASCOLOSOMA NIGRESCENS Keferstein

Fig. 9

Phascolosoma nigrescens Keferstein, 1865*b*, p. 424.
Physcosoma nigrescens Selenka & de Man, in Selenka, de Man, and Bülow, 1883, pp. 72-4.

Specimens examined, 14 (4 dissected).—QUEENSLAND (12): Wistari Reef, Capricorn Group, 2.viii.1947, "in coral", W. McIntyre; Heron I., 10.viii.1955, "in dead coral", S. J. Edmonds; Low Isles, Beach Rock, "in oyster zone", 16.viii.1954, Prof. W. Stephenson (Univ. of Qld.). WESTERN AUSTRALIA (2): from reef at Port Dennison (Univ. of W.A.).

Previous Australian records.—QUEENSLAND: Low Isles (Monro 1931). WESTERN AUSTRALIA: Cape Jaubert (Fischer 1921); Shark Bay (Fischer 1926).

Description

The specimens, some of which had been damaged probably during collection, are small and light brown in colour when alive. The length of the trunk is 1·5-2·6 cm and the maximum width about 3·5 mm. The introvert is about as long as the trunk and bears at least 30 rows of hooks, the structure and size of which are shown in Figure 9. The surface of the trunk and introvert is covered with tall, conical-shaped papillae, slightly darker in colour than the body wall. The papillae are largest and most prominent at the base of the introvert and at the posterior extremity of the trunk, where they are 0·1-0·2 mm in diameter. Poorly developed pigmented bands were present on the dorsal surface of the specimens with extended introverts.

There are about 20-24 longitudinal muscles which anastomose. A pair of stout ventral retractors arises from muscles 2-7 (2-8, 1-7) and a pair of more slender dorsal retractors more anteriorly from muscles 6-8 (7-9). The anterior part of the oesophagus is fastened to the retractors by fine mesenteries and the intestinal spirals are numerous. A stout spindle muscle is fixed anteriorly near the anus and posteriorly to the body wall. The rectum is fastened to the spindle muscle at a number of points. A single fastening muscle, arising near the left dorsal retractor, is fixed to the last whorl of the intestine. There is a strongly developed wing muscle and a contractile vessel with very small villi. No intestinal caecum was found. The nephridia are short and are fixed to the body wall for about two-thirds of their length. The nephridiopores lie between muscles 2-3 or 4-5 at about the same level as the anus.

Systematic position

The identification of these specimens depends largely on the structure of the introvert hooks. *P. nigrescens* is close to *P. puntarenae* Grube described from the Pacific coast of North and South America. *P. puntarenae* possesses a caecum (Fisher 1952, p. 431) while these specimens from Australia do not.

P. nigrescens is distinguished from other Australian forms by the structure of its hooks.

Distribution.—In Australia, the Great Barrier Reef and north-west Western Australia. It has been reported from Fiji, the Philippine Is., Japan, the Gulf of Siam, Ceylon, the Laccadive and Maldive Is., Zanzibar, Mauritius, and the Red Sea.

Phascolosoma lurco (Selenka & de Man)

Fig. 10

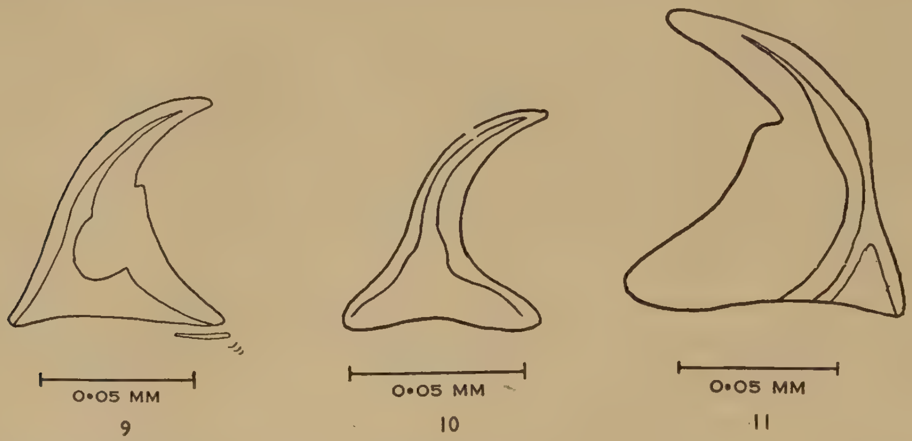
Physcosoma lurco Selenka & de Man, in Selenka, de Man, and Bülow, 1883, p. 61. Lanchester, 1905, p. 37.

Specimens examined, 16 (5 dissected).—QUEENSLAND: Sandgate, Dr. I. Hiscock (Univ. of Qld.); Low Isles, sand flat, south of lighthouse, Prof. W. Stephenson (Univ. of Qld.).

Previous Australian record.—QUEENSLAND: Rockhampton (Fischer 1914, p. 5).

Description

The trunk of the specimens is stout, almost uniformly cylindrical, 3-4·5 cm long and 6-9 mm wide. The specimens are brown in colour except at the anterior and posterior regions of the trunk, which are very dark brown. The introvert is about as long as the body, although in none of the specimens was it fully everted. Papillae on the introvert and mid body region are small and brown but on the anterior and posterior surfaces of the trunk they are large, prominent, and much darker. The largest papillae are 0·4-0·6 mm in diameter and consist of a large number of small polygonal plates. The introvert bears as many as 70 rows of hooks, the size and structure of which are shown in Figure 10. The papillae between the rows of hooks are very small and about 0·02 mm in diameter.



Figs. 9-11.—Introvert hooks. Fig. 9.—*Phascolosoma nigrescens*. Fig. 10.—*P. lurco*. Fig. 11.—*P. pacificum*.

About 18-21 stout, longitudinal muscles, which sometimes anastomose, are present. There is a tendency for the circular muscles to be grouped into strands, a fact shown in Selenka's drawing of *P. lurco* (Selenka, de Man, and Bülow 1883, Fig. 103). Four retractor muscles arise from the body wall in the posterior fourth of the animal. One pair arises from muscles 1-2 (2-3, 1-3) and a second more anteriorly from muscle 1 or 1-2. The 4 retractors remain separate for only a short distance, fusing to form a single, stout muscle.

A thin-walled oesophagus is firmly attached to the fused retractor for most of the length of the latter. A spindle muscle to which is attached a much-coiled intestine arises anteriorly near the anus and is fastened posteriorly to the body wall. The rectum is short. No caecum and no intestinal fastener, other than the spindle muscle, were found. A well-developed wing muscle is present and the anal aperture is at about the same level as the nephridiopores. Two yellow-brown nephridia, fixed to the body wall for about four-fifths of their length, open to the exterior between muscles 4-5 or 5-6. The region of the nephridia near the nephridiopore is considerably expanded. A fine contractile vessel runs along the section of the oesophagus which is attached to the retractors. No information can be given about the number of tentacles present.

Systematic position

The identification of this species depends on the structure of: (i) the hooks on the introvert; (ii) the 4 retractors, which are fused for most of their length into a single muscle. These specimens also resemble very closely *P. lurco* as described by Lanchester (1905, p. 37).

Distribution.—In Australia, Queensland. Other records: Malay Archipelago, Manila, China, and Indo-China.

PHASCOLOSOMA PACIFICUM Keferstein

Fig. 11

Phascolosoma pacificum Keferstein, 1867, pp. 49-50.
Physcosoma pacificum Selenka & de Man, in Selenka, de Man, and Bülow, 1883, p. 63.

Specimens examined, 3.—QUEENSLAND: Heron I., 10.viii.1955, "in dead coral", S. J. Edmonds.

Previous Australian record.—QUEENSLAND: Low Isles (Monro 1931).

Description

The trunk of the largest specimen is 6·5 cm long and the maximum width in the posterior third of the trunk nearly 2 cm. The introvert when expanded would be about as long as the body. The body wall is light brown in colour with a well-developed, darker brown mottling. Towards the anterior region of the trunk the dark brown markings become less irregular in outline and more band-like. The introvert bears a number of both complete and incomplete rows of light-brown hooks, the size and shape of which are shown in Figure 11. The body wall is thick and the longitudinal muscle bands are not visible externally. The surface of both the introvert and trunk bears numerous sharply pointed papillae, which are largest in the posterior region of the animal.

The longitudinal muscles are grouped into bundles which anastomose considerably so that it becomes difficult to give their number with certainty. Anteriorly there appear to be about 20 bundles and posteriorly about 38. There are 4 strong retractors. A stout ventral pair, arising near the ventral nerve cord in the posterior third of the trunk, spans about 6 muscle bands. A stout dorsal pair arises more anteriorly and spans almost the same 6 muscles. The retractors fuse anteriorly.

The intestine consists of numerous spirals which were full of coral fragments. The last whorl of the intestine is held firm by a strong fastening strand which is attached to the body wall just below the right dorsal retractor. A stout spindle muscle is fixed to the body wall near the anus. It fuses with the rectum at a number of points, holds together the spirals of the intestine, and is fastened posteriorly to the body wall. No intestinal caecum was found and the dorsal contractile vessel seems poorly developed.

A most noticeable character revealed on dissection is a pair of long, dark-coloured nephridia which extend to the posterior extremity of the body and which are attached to the body wall for their entire length. The nephridiopores are just anterior to the anus.

Systematic position

These specimens are identified by: (i) the structure of the hooks; (ii) the pair of long nephridia which extend to the posterior extremity of the trunk.

Distribution.—In Australia, the Great Barrier Reef. Other records: Mauritius, the Red Sea, the Maldive and Laccadive Is., Macassar, Amboina, New Guinea, Japan, Funafuti, and the Loyalty Is. It appears to be an Indo-Pacific species.

PHASCOLOSOMA DUNWICHI, sp. nov.

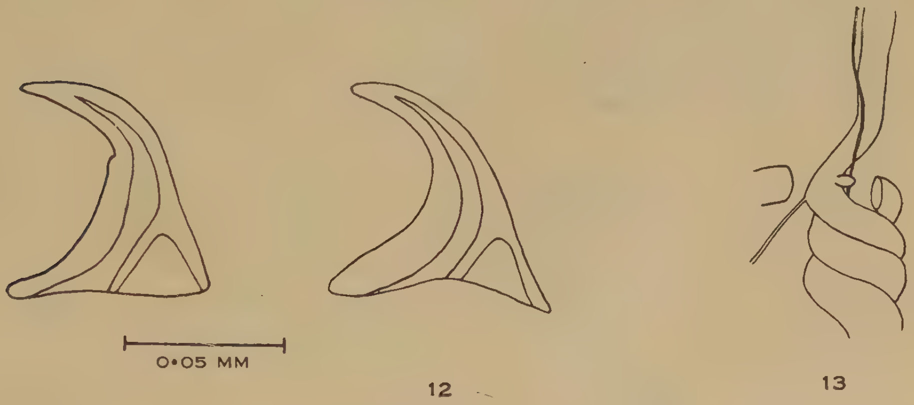
Figs. 12 and 13

Specimens examined, 31 (7 dissected).—QUEENSLAND: Dunwich, North Stradbroke I., "in mussel clumps" and "under oyster shells", 9.ix.1955, Dr. I. Hiscock (Univ. of Qld) (19 spec.); Myora, "in mussel formations", 25.ii.1946 (collection from Univ. of Qld.); Noosa, "amongst *Pyura*", 25.ii.1941, Sci. Students Ass. Exped. (Univ. of Qld.); Heron I., "in fissures and cracks between rocks near high water mark", Aug. 1955, S. J. Edmonds (5 spec.).

Description

The length of the trunk is 1·5-2·2 cm and the maximum width 3-6 mm. The colour of the specimens is light brown except at the anterior and posterior regions of the trunk, which are dark brown. The introvert is about as long as the trunk and bears 15-18 short, stout tentacles and from 14 to 45 rows of brown to light brown hooks, the structure of which are shown in Figure 12. The hooks resemble closely those of *P. scolops* as shown in Figure 139 of Selenka's monograph (Selenka, de Man, and Bülow 1883). The darker pigmented spot between the basal and central portion of the clear streak which appears in Selenka's Figure 139 is not present in *P. dunwichi*. The surface of the animal is covered with papillae made up of numerous small polygonal plates of uniform size. The papillae on the introvert are small and conical in shape while those on the anterior and posterior regions of the trunk are largest (max. dia. 0·4 mm), hemispherical in shape, dark brown in colour, and most densely packed. A varying number of darkly pigmented bands appears on the dorsal surface of the introvert.

The longitudinal musculature is grouped into about 20 anastomosing bundles, generally visible through the body wall. Two stout ventral retractors arise in the posterior half of the trunk from muscles 2-7 (1-6, 2-6) and 2 more slender dorsal retractors more anteriorly from muscles 6-7 (5-7, 6-8). The retractors in each side fuse anteriorly. A single fastener arises from muscle 1 near the left dorsal retractor. It bifurcates, giving off 1 short root to the oesophagus and another to the last whorl of the intestine. There is a spindle muscle, which is fastened anteriorly near the anus and posteriorly to the body wall, and a well-developed rectal caecum. The nephridia are brown in colour, extend to the base of the dorsal retractors, and are fixed to the body wall by a thin mesentery for about half their length. The nephridial aperture lies between muscles 2-3 or 3-4.



Figs. 12-13.—*Phascolosoma dunwichi.* Fig. 12.—Introvert hooks. Fig. 13.—Part of alimentary canal showing caecum.

Systematic position

The hooks of these specimens are very close to those of *P. scolops*. The plates of the papillae, however, are uniform in size and very densely packed. There is no ring of larger plates around the pore of the papillae as shown in Figure 144 of Selenka (Selenka, de Man, and Bülow 1883). The specimens also possess a rectal diverticulum, a structure neither described by Selenka (Selenka, de Man, and Bülow 1883) nor reported for *P. scolops* by Sato (1930, p. 13) or Wesenberg-Lund (1937, p. 9). They are described as a new species.

The specimens have been found in similar habitats at Dunwich, Myora, and Noosa. The specimens from Heron I. were not collected from coral but from cracks and fissures between the rocks of consolidated coral sand which fringe the island near high water level.

Type locality.—Dunwich, North Stradbroke I., Qld.
Type specimen.—Australian Museum, Sydney.
Distribution.—Queensland.

PHASCOLOSOMA HERONIS, sp. nov.

Fig. 14

Physcosoma scolops Monro, 1931, p. 35.

Specimens examined, 25 (8 dissected).—QUEENSLAND: Heron I. (Capricorn Group), "boring into coral rock", Aug. 1954, Dr. I. Hiscock (Univ. of Qld.) (3 spec.); Heron I., "in coral rocks exposed at low tides", 16.viii.1955, S. J. Edmonds (20 spec.); Low Isles, "in dead coral", Jan. 1954, Prof. W. Stephenson (Univ. of Qld.) (2 spec.).

Description

In many respects this species is like *P. rottnesti* and *P. dunwichi*. It differs from both, however, in: (i) the structure of the hook; (ii) the distribution of its papillae; (iii) its colour. The length of the trunk of the specimens is 1·5-3·0 cm and the maximum width 3·5-5·5 mm. The trunk of the specimens is pale straw or off-white except anteriorly where it is brown like the introvert. Unlike most other related sipunculids the posterior extremity of the trunk is the same colour as, or just a little darker than, the trunk. The introvert is about as long as the trunk and bears 14-18 short, digitform, white tentacles, a varying number of darkly pigmented bands, and numerous rows of very dark brown hooks, the size and structure of which are shown in Figure 14. The hooks are different from those of *P. dunwichi*; they are darker in colour, the clear streak is narrower and more smoothly curved, and on one side of the clear streak at the base of the hook there is a clear crescentic area and on the other a clear triangular area. They resemble to some extent the hooks of *P. scolops* var. *mossambicense* shown in Figure 140 of Selenka (Selenka, de Man, and Bülow 1883). The papillae on the introvert are usually dark in colour and sharply conical. In some cases they are almost hook-like, resembling the papillae of *P. dentigerum* as shown in Figure 120 of Selenka (Selenka, de Man, and Bülow 1883) except that they are not always posteriorly directed. The structure of the introvert hook is, however, different from that of *P. dentigerum* as shown in Figure 118 of Selenka (Selenka, de Man, and Bülow 1883). The papillae on the anterior region of the trunk are more numerous, flatter, and less conical, and consist of small chitinous plates of approximately uniform size. The papillae on the rest of the trunk, including the posterior region, are much more scattered. While they do increase slightly in size, the posterior papillae are never as densely packed or as dark as those which occur on the posterior surface of *P. rottnesti*, *P. dunwichi*, and *P. tasmaniense*. In some specimens the papillae have lost the small

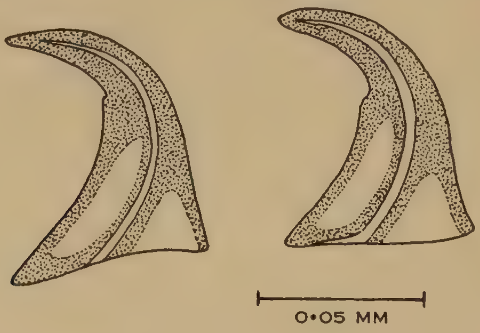


Fig. 14.—*Phascolosoma heronis*. Introvert hooks.

superficial plates and then appear to be made up of long, radially arranged plates. The plates in these specimens have become detached, probably while the animal was being removed from its "burrow" in the coral.

Internally the specimens are similar to those of *P. rottnesti* and *P. dunwichi*. There are 20-25 anastomosing longitudinal muscle bands and 4 introvert retractors. A stout ventral pair arises from muscles 2-6 (1-5, 2-7) and a more slender dorsal pair more anteriorly from muscles 5-8 (5-7). The fastening muscle is like that of *P. dunwichi*. A spindle muscle is fastened anteriorly near the anus and posteriorly to the body wall. There is a rectal caecum and strong wing muscles. The gonads lie at the base of the ventral retractors. The nephridia are brown, extend as far as the base of the dorsal retractors, and are fixed to the body wall for about half their length. They open to the exterior between muscles 2-3 or 3-4. There are 2 small eyespots near the brain. The eggs are subspherical and about 0·10-0·12 mm in diameter.

Systematic position

This species differs from other Australian species in the structure of its introvert hooks and the distribution of its papillae. It has been found only in coral rock. The hooks of one of the specimens from Low Isles identified by Monro (1931, p. 31) as *P. scolops* are identical with those obtained from the Heron I. specimens. Monro's specimen was made available for examination by the authorities of the British Museum, London.

Type locality.—Heron I., Capricorn Group, Qld.
Type specimen.—Australian Museum, Sydney.
Distribution.—Queensland.

PHASCOLOSOMA DENTIGERUM (Selenka & de Man)

Physcosoma dentigerum Selenka & de Man, in Selenka, de Man, and Bülow, 1883, p. 67.
Phascolosoma dentigerum Fisher, 1952, p. 432.

Australian record.—QUEENSLAND: Low Isles (Monro 1931).

Remarks.—On the introvert of this species there are 16-22 rows of sharply bent hooks and on the dorsal surface of the introvert and the posterior surface of the trunk there are numerous prominent, conical or sharply pointed papillae.

PHASCOLOSOMA NIGRITORQUATUM Sluiter

Phascolosoma nigritorquatum Sluiter, 1881, p. 151.
Physcosoma nigritorquatum Selenka & de Man, in Selenka, de Man, and Bülow, 1883, p. 68.

Australian records.—WESTERN AUSTRALIA: Cape Jaubert (Fischer 1921), Shark Bay (Fischer 1926).

Remarks.—The introvert of this species bears only 4 rows of hooks. Around the margin of the mouth there is "eine Reihe intens schwarzer Körner und Wülste".

Genus DENDROSTOMUM

Dendrostomum Grube, in Grube and Oersted, 1859, p. 118.
Dendrostoma Keferstein, 1865*a*, p. 207.

Diagnosis

Sipunculids with 4 to 8 branching, grooved tentacles, which bear numerous small tentacules. Four primary food grooves which branch to the tentacles. Longitudinal musculature continuous and not divided into bundles. Retractors usually 2. Spindle muscle arises anteriorly near the anus but is not attached posteriorly. Usually 3 fixing muscles or intestinal fasteners. Two nephridia which hang free in the body cavity. Contractile vessel with few to many long or short Polian tubules. With or without hooks or spines on the introvert.

Type, *Dendrostomum alutaceum* Grube (Grube and Oersted 1859, p. 118).

Remarks.—Fisher (1952, p. 404) has pointed out that this genus should be called *Dendrostomum* and not *Dendrostoma.*

DENDROSTOMUM DEHAMATUM Kesteven

Plate 1, Fig. 1

Dendrostoma dehamata Kesteven, 1903, p. 69.

Specimens examined, 3.—NEW SOUTH WALES: Balmoral (near Port Jackson), "washed up after storm", July 1901 (Aust. Mus., Sydney, W1647, 1654, 1657).

Description

The animals examined were 3 of Kesteven's original specimens made available for re-examination by the authorities of the Australian Museum. Although externally the sipunculids were in a good state of preservation, internally the long, slender, and rather frail alimentary canal and its fasteners had deteriorated and become very soft. Consequently it was difficult to trace satisfactorily the oesophageal and intestinal loops and their associated structures in 2 of the specimens. Moreover in none was the introvert extended. Only a limited amount of information, then, can be given as a result of the re-examination. Two facts, however, not mentioned by Kesteven (1903) in his detailed description were noticed. Firstly, a small rectal caecum was present in 2 of the specimens; secondly, some variation in the system of intestinal fasteners as described by Kesteven seemed to occur.

The specimens are long, slender, almost uniformly cylindrical, white to grey in colour and in the preserved state coiled. Posteriorly the worms gradually taper to a point and in 1 specimen this region is black in colour. The length of the animals is about 16, 25, and 28 cm respectively and the diameter 0·5-0·8 cm. The introvert, judging from dissected specimens, would be about 5-7 cm long. Kesteven (1903) states that the introvert does not possess spines or hooks and that the tentacles are plumose and blotched with dark brown. Concerning their arrangement he says: "There are four narrow stems, two of two and two of three primary branches. In some specimens, however, the division between the branches extends right down to the circumoral muscular ridge, in which case there are eight branches arranged in groups as above. The stems are connected by a narrow, filamentous flap". Small white papillae or "tubercles" (Kesteven), 0·1-0·2 mm in diameter, cover the surface of the body; they are largest in the anterior region. A small glandular opening can be observed in the centre of each papilla.

Two long and rather slender retractors arise in the posterior third of the animal. A long oesophagus reaches almost to the posterior of the body. Attached to it is a contractile vessel bearing numerous villi which gradually increase in size posteriorly. The rectum is very long and carries a small diverticulum near which arises a fastener connected to the body wall at a point underneath the right retractor. No anterior spindle muscle was observed. Another fastener (presumably the sp.m.I of Kesteven's Fig. 1) arises in 2 specimens not alongside the left muscle as shown by Kesteven but from a point considerably posterior to it. In 1 specimen the 2 posterior oesophageal fasteners (Kesteven's mes.I and mes.II) are present. In the other specimen one (mes.I) is absent.

Systematic position

This species is very long and slender. These two characters distinguish it from other Australian species of the same genus.

Type locality.—Balmoral (near Port Jackson), N.S.W.

Type specimen.—Australian Museum, Sydney.

Distribution.—New South Wales.

DENDROSTOMUM SIGNIFER Selenka & de Man

Plate 1, Fig. 2

Dendrostoma signifer Selenka & de Man, in Selenka, de Man, and Bülow, 1883, p. 86 (in part).

Specimens examined, 51 (10 dissected).—QUEENSLAND: Yeppoon, "very common between rocks and in mussel clumps", 18.i.1953, Prof. W. Stephenson (Univ. of Qld.); Dunwich, near Brisbane, "in crevices either between mussels or oyster shells or beneath oyster shells", 2.ix.1955, Dr. I. Hiscock (Univ. of Qld.).

Previous Australian records.—QUEENSLAND: Cape York (Selenka, de Man, and Bülow 1883). Varieties with hooks have been reported from Sydney, N.S.W. (Selenka, de Man, and Bülow 1883), Tasmania (Fischer 1914), and Albany, W.A. (Fischer 1926).

Description

The specimens are small, the trunk being 16-26 mm long and the extended introvert 5-7 mm. The maximum width in the posterior third of the trunk is 7-9 mm and the width of the introvert 2-3 mm. Although small, the specimens are considered to be adults because eggs were found in the body cavities of 5 of them. Animals recently fixed in 70 per cent. alcohol are light brown to grey in colour, the anterior region of the trunk and the introvert being slightly darker. All the specimens curve inwards on the ventral side.

The tentacules are white and show no sign of pigmentation or flecking as described for *D. dehamatum* and *D. cymodoceae.* They are numerous and arise from 4 primary stems, each of which may divide into 2 or more substems which in turn give off the tentacules. The tentacules are comparatively long. The ratio of the length of the tentacules (2-3 mm) to the length of the trunk (19-26 mm) is considerably greater than in the related *D. cymodoceae* where the corresponding measurements are 2-3 mm and 50-90 mm. The introvert does not bear hooks. In all the specimens there is a dark blue-black band in the mid region of the introvert. The surface of the trunk bears numerous small, flat papillae which are more scattered posteriorly. The skin of all the specimens is considerably furrowed, both transversally and longitudinally.

There are 2 very stout ventral retractors which arise in the posterior half of the body. There are 3 fixing muscles. An oesophageal loop is fastened to the body wall by a very short mesentery or muscle which arises between the ventral retractors. A second fastener arises from the body wall just anterior to the point of insertion of the left retractor and is fixed to the oesophagus near the first intestinal coil. A third fastener arises near the right retractor and is connected to the last whorl of the intestine. The rectum is short and bears a small caecum. There is a well-developed wing muscle and the nephridia, about half as long as the trunk, hang free. There is a stout spindle muscle which arises from the rectum at a point near the rectal diverticulum. A contractile vessel with numerous branching and finger-like villi extends along the oesophagus as far as the base of the retractors. Eggs in the body cavity are spherical and about 0·10 mm in diameter. A nuchal organ is present anteriorly on the dorsal surface of the introvert.

Systematic position

D. signifer was described by Selenka (Selenka, de Man, and Bülow 1883) from specimens collected at the Philippine Is., Singapore, and Cape York (presumably Qld.). The specimens from Yeppoon, Qld., correspond in most respects with Selenka's description of the species. Selenka, however, describes the tentacles as arising from 5-6 stems, whereas in the present material they arise clearly from 4, and he makes no mention of a rectal diverticulum. On the other hand Augener (1903, p. 301) reports the presence of a rectal caecum in his specimens of *D. signifer* from Amboina, and Ikeda (1904, p. 56) describes *D. signifer* from the Riukui Is., Japan, with 4 main tentacular stems and a rectal diverticulum. In view of these facts and the proximity of Cape York and Yeppoon, Qld., these specimens are identified as *D. signifer*.

Selenka (Selenka, de Man, and Bülow 1883) also refers to a variety of *D. signifer* from Sydney, N.S.W., which bears posteriorly directed hooks about 0·2 mm long. He says: "Wir stehen nicht an, diese Form lediglich als an Varietät zu betrachten, bei welcher die Haken nicht fruhzeitig ausfallen, sondern erhalten bleiben, ein Unterschied der auf differente Lebenweise vermuthlich zurüchzuführen ist". This hooked variety has also been reported from New Zealand (Augener 1903, p. 337) and Tasmania (Fischer 1914, p. 10). No specimens corresponding to this hooked variety were in the collection examined by the present author.

Fischer (1919) describes a form of *D. signifer* from Albany, W.A., in which the hooks are arranged in a somewhat different way. Instead of pointing posteriorly the hooks are irregularly directed very much as Fischer (1914, p. 11) described for his specimens from Tasmania and New Zealand: "Sie stehen nicht in Reihen sondern regellos, oben dichter als unten, und sind merkwürdigerweise alle verschieden gerichtet, einige mit der Spitze nach oben, andere nach unten oder auch seitwarts".

Two adult specimens of this form collected from Garden I., near Perth, W.A., have been examined by the present author. Although they closely resemble *D. signifer* in internal anatomy, their identification is being withheld until more specimens are available for study. Although Awati and Pradhan (1935) found that the hooks of the juvenile specimens of their *D. signifer* from India "fall off" when the animals are full grown, it is possible that the armed varieties from Australia may be a new species. In the present paper, only the form without hooks from Queensland is regarded as *D. signifer*.

Distribution.—In Australia, Queensland. Varieties with hooks have been reported from Sydney, Tasmania, and Western Australia. Other records: the Philippine Is., Singapore, Batavia, Billiton, New Zealand, and Dutch South West Africa.

DENDROSTOMUM CYMODOCEAE, sp. nov.

Figs. 15 and 16; Plate 2, Fig. 1

Specimens, about 250 *juveniles and adults* (40 dissected).—SOUTH AUSTRALIA: Aldinga Beach, St. Vincent's Gulf; Port Victoria, Spencer's Gulf.

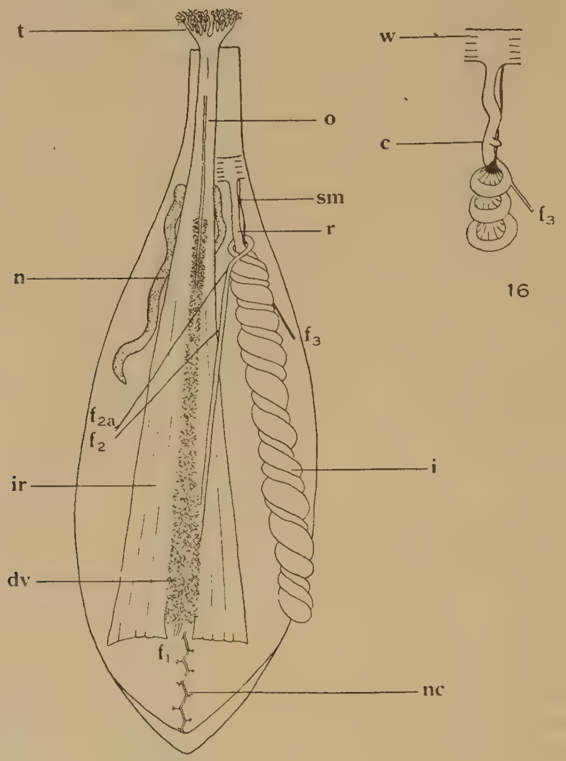
Habitat

All the specimens were found in sand amongst the matted roots of the marine angiosperm, *Cymodocea antarctica* F. Muell., which forms extensive beds just below the level of low-water spring tide in sandy bays and sandy gulfs in South Australia. The animals are best obtained by digging out a square of the roots, turning over the sample and picking them out posterior end first. They are particularly hardy and will survive in aerated sea-water without much attention for as long as 4 months.

Description

The adult form of this sipunculid is large, robust, and elongate-pyriform in shape. The length of the trunk is 5-9 cm and its maximum width (posteriorly) is 1·5-2·5 cm. The introvert is cylindrical and relatively short, 1·5-2·5 cm long and about 0·70-0·55 cm in diameter. No spines or hooks occur on the introvert of either juvenile or adult specimens. The trunk is usually light to dark grey or sometimes light brown in colour, the posterior region usually being darker. In some specimens the posterior region is almost blue-black. The introvert is usually pale grey. The surface just posterior to the tentacles is very smooth, pale, and shiny and in some instances may be purplish and glossy. There is usually a light brown or yellow pigmented band around the surface of the introvert near its middle. The body wall appears and feels smooth. Closer examination shows that the surface is covered with numerous small, white papillae 0·04-0·08 mm in diameter, each of which bears at its centre a small, white glandular opening. The anal aperture in relaxed and resting forms is about 1·5-2·5 mm posterior to the tentacular crown. The body wall is thick, especially posteriorly. The interior or coelomic surface of the body is glistening white and is traversed by oblique muscle striations.

The tentacles arise from 4 primary stems which usually subdivide into secondary stems. Consequently at first sight there may sometimes appear to be as many as 6 to 8 groups of tentacles. The tentacules or the small finger-like structures are very numerous, pale straw to light purple-brown in colour. The anterior tip of the tentacles is always darker than the rest of the structure. The tentacles are 2-3 mm long. Relative to the length of the body (50-90 mm) they are smaller than the tentacules of *D. signifer*.



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Figs. 15-16.—*Dendrostomum cymodoceae.* Fig. 15.—Dissected specimen. *dv*, dorsal contractile vessel; *f*, fastener; *i*, intestine; *ir*, introvert retractor; *n*, nephridium; *nc*, nerve cord; *o*, oesophagus; *r*, rectum; *sm*, spindle muscle; *t*, tentacles. Fig. 16.—Posterior region of intestine, showing position of caecum and method of attachment of intestine to the spindle muscle.

The internal anatomy of the specimens resembles that of *D. signifer* so closely that it is difficult to find any constant difference between the two. Usually, however, the system of fasteners in *D. cymodoceae* is more complex than in *D. signifer*. There are 2 very long and stout retractors arising in the posterior fourth of the animal. A thin-walled oesophagus runs between the retractors as far as the base, then loops sharply upward to a point about 1 cm posterior to the anal aperture, where it becomes coiled into the intestine. The latter is long and reaches to the posterior of the animal. The rectum is short and thick-walled and bears a caecum which in some specimens is slightly pointed. The system of intestinal anchors or fasteners varies to some extent in different specimens. The downward loop of the oesophagus is fastened to the body wall at a point near the base of the retractors by 1-4 fine, short threads (f_1) which arise between the base of the retractors usually on the left side of the nerve cord (dorsal view). A second fastener (f_2) arises on the left side of the left retractor in the mid body region and is connected to the upward loop of the oesophagus at a point near the intestine. In some specimens f_2 bifurcates, supplying 2 oesophageal fasteners. In about half the specimens examined an additional fastener (f_{2a}) arises close to f_2 and connects with the oesophagus. A third anchor (f_3), present in all specimens, is usually shorter and stouter than f_2 and arises on the right side of the right retractor in the mid body region. It is joined to the intestine near its last whorl. A strong spindle muscle arises posterior to the anal aperture from below a sheet of tissue or wing muscle, very much as in a number of other species of *Dendrostomum*. It runs very close to and in some cases is attached to the rectum and then between the whorls of the intestine, giving off short, stout threads to the coils of that organ. The spindle muscle is not fixed posteriorly. The nephridial apertures are just posterior to the anal aperture. The nephridia are long, brown in colour, thin and free, and extend as far as the mid region of the body. A well-developed contractile vessel lies along the dorsal surface of the oesophagus as far as the base of the retractors. It bears numerous branching villi or caeca which are very densely clustered posteriorly. A single villus or caecum may be as long as 5 mm. Ripe eggs are spherical, white, and about 0·13 mm in diameter. There seems to be considerable disparity in numbers between the two sexes, many more females being collected than males.

Juvenile specimens are considerably more elongate and paler in colour than the adults and more active when alive.

Systematic position

These specimens are closely allied to *D. signifer* Selenka & de Man, previously reported from a number of different localities in Australia and from Queensland in the present paper. Very little difference can be found between the internal anatomy of the specimens from Queensland and South Australia. They can, however, be separated readily into two groups for the following reasons. The specimens from South Australia: (i) are very much larger than those from Queensland; (ii) possess a rusty yellow pigmented band on the introvert whereas those from Queensland possess a dark blue band; (iii) have relatively smaller tentacles which (iv) are pigmented anteriorly, unlike the Queensland specimens; (v) there is greater complexity and variation in the arrangement of the intestinal fastener of the specimens from Aldinga. For these reasons they are regarded as new. They are called *D. cymodoceae* because they have been found associated only with the angiosperm *Cymodocea antarctica*. It is possible that *D. signifer* from Queensland as understood in this paper and *D. cymodoceae* may represent extreme geographic variations of one species. From the evidence available at present this is considered not to be so.

Genus GOLFINGIA Lankester

Phascolosomum Diesing, 1851, p. 63 (in part).
Phascolosoma Selenka & Bülow, in Selenka, de Man, and Bülow, 1883, p. 15.
Golfingia Lankester, 1885, p. 469 (type *G. macintoshii* Lankester).*

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* Stephen (1934, p. 169) states that *G. macintoshii* is synonomous with *Phascolosoma vulgare* (de Blainville).

Diagnosis

Usually small or moderate in size and rather slender. Longitudinal musculature continuous and not divided into separate bundles except in *G. gouldii*. Tentacles finger-shaped, leaf-shaped, or filiform, arranged around the mouth in 1 or more rows and interrupted in the median dorsal line by the nuchal organ. Hooks may or may not be present on the introvert. There are 2 or 4 introvert retractors. Contractile vessel usually simple but villi are present in some forms. Spindle muscle usually not attached posteriorly to the body wall. Nephridia hang free. A pair of photic tubes leads from the surface of the cerebral sense organ to the substance of the cerebral ganglion.

Remarks.—Fisher (1950, p. 548; 1952, p. 388) has shown that the name *Phascolosoma* cannot be used for this group if the accepted rules of nomenclature are followed, and has revived the name *Golfingia* to replace the *Phascolosoma* of different authors. Fisher's terminology has been adopted by Wesenberg-Lund (1954*a*, 1954*b*) and is used in the present paper.

GOLFINGIA MARGARITACEA (Sars) ADELAIDENSIS, subsp. nov.

Plate 2, Fig. 2

Specimens examined, 12.—SOUTH AUSTRALIA: Aldinga Beach, St. Vincent's Gulf (about 30 miles south of Adelaide).

Habitat

The animals were collected in sand from amongst the roots of the marine angiosperms *Cymodocea antarctica* and *Zostera muelleri* Irmisch, just below the level of the low spring tides.

Description

The specimens are long, slender, and rather active when alive. They are yellow-brown in colour and tend to glisten. The length of the trunk is 7-10 cm and the maximum width 4-7 mm. The posterior extremity tapers to a sharp point. The body surface bears numerous small papillae which are best developed on the anterior and posterior regions of the trunk. They appear as white, circular or elliptical structures about 0·1-0·2 mm in diameter, in a yellow matrix of the body wall. They are densest posteriorly. The introvert is slender and comparatively short, 2-2·5 cm long and 2-3 mm wide. It does not bear hooks. The anterior extremity of the introvert in both living and preserved specimens is swollen into a bulbous structure 3·5–5 mm in diameter, similar to that for *G. margaritacea* shown by Theel (1905, Fig. 20) and for *G. fusca* by Michaelsen (1889, Fig. 2*a*). The tentacles are short (2-3 mm long) and white and about 80 in number. The body wall is smooth and thin except at the anterior and posterior regions of the trunk where it is thicker. No fine reticular markings are present on the surface as reported by Selenka (Selenka, de Man, and Bülow 1883).

There are 2 well-developed ventral retractors which arise close to the nerve cord in the anterior third of the trunk and 2 more slender dorsal retractors which arise more anteriorly near the level of the anus. The retractors are separate almost for their entire length. The coelomic surface of the body is white and glistening. The oesophagus is short and fastened anteriorly by their mesenteries to the dorsal retractors. The intestine is long, consisting of at least 20 spirals. A spindle muscle which arises anteriorly near the anus is connected by a thin mesentery to the rectum and is not attached to the body wall posteriorly. There are at least 2 and in some cases 3 well-developed ribbon-like intestinal fasteners. One arises from the body wall just below the left dorsal retractor and is connected to the oesophagus. This fastener bifurcates in 2 specimens. A second and sometimes a third fastener arise from the body wall between the right dorsal and ventral retractors and connect with the last whorl of the intestine. Either of these last 2 fasteners may bifurcate as well.

The nephridia are long and brown, hang free, and are expanded near the body wall. The nephridiopores are just anterior to the anal apertures. The contractile vessel is well developed but lacks villi. The rectum is short and lacks a well-developed caecum although in 2 specimens a rudimentary caecum may have been present. Two small eyespots are situated near the brain. The gonads lie at the base of the ventral retractors and eggs 0·15-0·18 mm in diameter were present in 1 specimen.

Systematic position

This species, possessing four retractors but lacking introvert hooks, differs from all the species of *Golfingia* previously reported from Australia. *G. schuttei* (Augener), *G. pellucida* (Keferstein), and *G. misakiana* (Ikeda) possess introvert hooks, and *G. semperi* (Selenka & de Man) while lacking introvert hooks possesses only two retractors.

These specimens are very close anatomically to *G. margaritacea* (Sars), described from the northern hemisphere and reported from the Antarctic and sub-Antarctic by a number of different workers (Stephen (1941, p. 251) has summarized its distribution in the southern hemisphere). Fischer (1896, p. 5), Theel (1911, p. 27), and Stephen (1941, p. 253) consider *G. margaritacea* to be a bipolar species. Wesenberg-Lund (1954*c*, p. 200) says that it is "most probably cosmopolitan". It is difficult to select any character which might be used to distinguish these Australian specimens from *G. margaritacea*. The tentacles of the Australian specimens are more numerous (Fisher (1952, p. 392) says that the number of tentacles of *G. margaritacea* increases with the size of the specimen); no reticular pigmentation occurs in their trunk (much like *G. margaritacea subirica* Theel (Theel 1905, p. 64)); and a caecum is lacking or possibly rudimentary in them (like *G. margaritacea californiensis* Fisher (Fisher 1952)). Consequently they are considered to be a new subspecies, *G. margaritacea adelaidensis*.

Type specimen.—Australian Museum, Sydney.

Type locality.—Aldinga Beach, St. Vincent's Gulf, S.A.

GOLFINGIA VULGARIS (Blainville) QUEENSLANDENSIS, subsp. nov.

Fig. 17

Specimens examined, 2.—QUEENSLAND: Heron I., Aug. 1955, "in coral sand under large coral rock", H. Carrol (1 spec.) and S. J. Edmonds (1 spec.).

Description

The specimens when alive are white, glistening, thin-walled, and almost transparent. The trunk of the larger specimen when fixed is about 5 cm long and its width, which is almost uniform, 4-5 mm. A slender introvert about half as long as the trunk bears 15-18 short, stout, white tentacles. A narrow region of the introvert posterior to the tentacular crown is armed with small yellow spines or hooks which arise from swellings of the epidermis and which are not quite arranged in transverse rows. Anteriorly the hooks are 0·12-0·18 mm long but posteriorly they are flatter and not as tall. The anterior and posterior extremities of the trunk are differentiated as more or less conical regions slightly darker than the rest of the body. The introvert and the anterior and posterior trunk regions are covered with numerous hemispherical to tubular papillae about 0·05 mm in diameter and from 0·05 to 0·07 mm tall. Minute openings or pores, possibly glandular, occur in the remainder of the trunk.

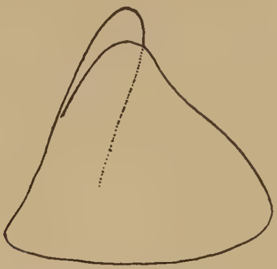


Fig. 17.—*Golfingia vulgaris queenslandensis.* Introvert spine.

The longitudinal musculature is continuous. There are 4 retractors. Two ribbon-like ventral retractors arise in the middle of the trunk and 2 more slender dorsal retractors more anteriorly. A spindle muscle is attached to the body wall anteriorly near the anus but not posteriorly. A thin-walled intestine of about 30 spirals is filled with small fragments of coral. There are 3 fine fasteners. Two arise close together from the body wall just posterior to the left dorsal retractor and the third posterior to the right dorsal retractor. Of those from the left one is fastened to the anterior region of the oesophagus and the other to the posterior region of the intestine. The one from the right is fastened to the posterior region of the intestine. The rectum is short and filled with coral fragments, making it difficult to determine whether a caecum is present or not. Two long and free nephridia arise at about the same level as or just anterior to the anal aperture.

Systematic position

These specimens differ from the species of *Golfingia* previously reported in Australia. In *G. misakiana* (Ikeda) the introvert hooks possess accessory teeth and no fixing muscles are present, and in *G. schuttei* (Augener), *S. semperi* (Selenka & de Man), and *G. pellucida* (Kef.) there are only two retractor muscles.

The two specimens from Queensland resemble very closely *Golfingia vulgaris* (de Blainville), a species described from the colder waters of the northern hemisphere. On a number of different occasions, however, specimens from the Indo-Pacific region have been identified as *G. vulgaris*; e.g. *G. vulgaris* var. *tropicum* from the Indian Archipelago (Sluiter 1902, p. 33) and Japan (Sato 1934, p. 3); *G. vulgaris* "in coral sand" from Formosa (Sato 1939, p. 404), from Billiton (Fischer 1922, p. 17), the Red Sea (Selenka 1883, p. 23), and Zanzibar (Lanchester 1905, p. 31; Stephen 1952, p. 438). There seems no doubt that one or more forms closely allied morphologically to *G. vulgaris* occur in the Indo-Pacific regions. It is possible that these two specimens from the Great Barrier Reef may belong to a new species. Until more specimens are available for a more complete examination it is considered advisable not to invent a new name but to regard them as a subspecies of *G. vulgaris*, viz. *G. vulgaris* subsp. *queenslandensis*. *G. vulgaris* var. *tropicum* has been collected only at considerable depths (Sluiter 1902; Sato 1934).

Type specimens.—Australian Museum, Sydney.

Type locality.—Heron I., Great Barrier Reef, Qld.

GOLFINGIA PELLUCIDA (Keferstein)

Phascolosoma pellucidum Keferstein, 1865*b*, p. 433.

Australian record.—WESTERN AUSTRALIA: Cockburn Sound; Port Royal and Fremantle (Fischer 1926). NORTHERN AUSTRALIA: Torres Strait (Selenka 1883).

Remarks.—This species possesses 2 retractor muscles and hooks on the introvert.

GOLFINGIA MISAKIANA (Ikeda)

Phascolosoma misakianum Ikeda, 1904, p. 7.

Australian record.—WESTERN AUSTRALIA: Shark Bay (Fischer 1926).

Remarks.—This species possesses 4 retractor muscles and introvert hooks.

GOLFINGIA SCHUTTEI (Augener)

Phascolosoma schuttei Augener, 1903, pp. 335-7.

Australian record.—NEW SOUTH WALES: Sydney (Augener 1903).

Remarks.—This species bears hooks on the introvert and possesses 2 retractor muscles.

GOLFINGIA SEMPERI (Selenka & Bülow)

Phascolosoma semperi Selenka & Bülow, in Selenka, de Man, and Bülow, 1883, p. 37.

Australian record.—WESTERN AUSTRALIA: Cape Jaubert (Fischer 1921).

Remarks.—This species lacks hooks on the introvert and possesses 2 retractor muscles.

Genus ASPIDOSIPHON Diesing

Aspidosiphon Diesing, 1851, pp. 67-8.
Aspidosiphon Selenka & Bülow, in Selenka, de Man, and Bülow, 1883, p. 114.

Diagnosis

A horny or calcareous shield-like structure present at both extremities of the trunk. Introvert arises from the ventral side of the anterior shield. Hooks usually present on the introvert. Longitudinal muscle layers continuous or divided into separate bundles. Only 1 pair of retractors which are more or less fused.

Type, *Aspidosiphon mulleri* Diesing (Diesing 1851, p. 68).

Aspidosiphon hartmeyeri Fischer

Fig. 18

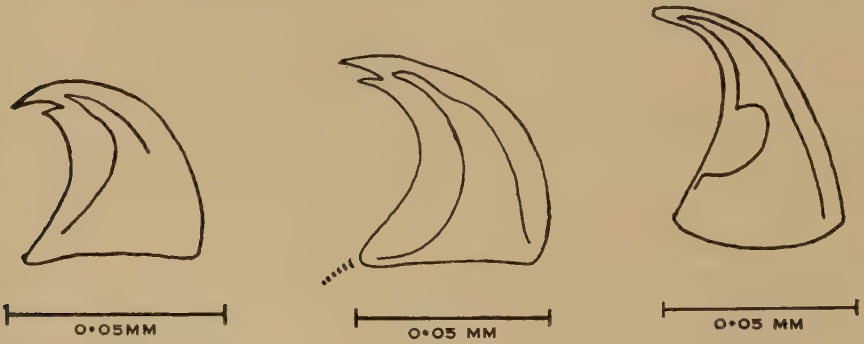
Aspidosiphon hartmeyeri Fischer, 1919, p. 277. Fischer, 1926, p. 204.

Specimens examined, 5.—WESTERN AUSTRALIA: Rottnest I. (off Fremantle), 24.x.1954, "found in burrows in a calcareous rock platform", Dr. Hodgkins (Univ. of W.A.).

Previous Australian record.—WESTERN AUSTRALIA: Shark Bay (Fischer 1919).

Description

The specimens are small, curved ventrally to some extent, and pale straw in colour except for the anal and caudal shields, which are brown. The trunk of the specimens is 10-14 mm long and its maximum width 2-3·5 mm posteriorly. One fully extended introvert is 10 mm long and about 0·7-1·0 mm wide, and bears 8 tentacles and numerous rows of hooks with double points (Fig. 18). Slender, slightly curved, irregularly placed spines appear between the posterior rows of hooks and extend posteriorly over the surface of the organ. The papillae on the trunk are flat and consist of numerous polygonal plates. Those anteriorly and posteriorly are largest and are 0·05–0·15 mm in diameter.



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Figs. 18-20.—Introvert hooks. Fig. 18.—*Aspidosiphon hartmeyeri*. Fig. 19.—*A. steenstrupii*. Fig. 20.—*A. klunzingeri*.

The body wall is smooth and the longitudinal musculature continuous. The circular muscles are grouped more or less into anastomosing bundles most readily observed when the animal is dissected. This probably accounts for the "Querstreifung" noticed by Fischer (1919). The anal and caudal shields are brown to dark brown in colour and are composed of thick polygonal plates. The anterior or anal shield is oval in shape and the posterior or caudal shield is circular and somewhat larger. According to Fischer (1919) the anterior shield shows 5-6 and the posterior 24-25 furrows. The furrows were not well developed in the present specimens.

There is a stout introvert retractor which is fastened by 2 roots to the body wall near the caudal shield. The oesophagus is short and attached to the introvert retractor for most of its length. The intestine is not coiled to the same extent as in most sipunculids. It is held in position by a spindle muscle which is fixed anteriorly near the anus and posteriorly to the body wall. A fastening muscle, arising from the last whorl of the intestine, runs beneath the 2 roots of the retractor to the body wall. The rectum is rather long and bears a caecum. The nephridia are long and free and the nephridial aperture is posterior to the anal aperture.

Systematic position

This species can be distinguished from other Australian members of the genus by: (i) the fact that its longitudinal musculature is continuous; (ii) the shape of the hooks on the introvert.

Type locality.—Shark Bay, W.A.

Distribution.—Known only from Western Australia.

ASPIDOSIPHON STEENSTRUPII Diesing

Fig. 19

Aspidosiphon steenstrupii Diesing, 1859, p. 767.

Aspidosiphon steenstrupii Selenka & de Man, in Selenka, de Man, and Bülow, 1883, p. 116.

Specimens examined, 5.—QUEENSLAND: Wistari Reef, Capricorn Group, 17.viii.1955, "in dead coral exposed at low tide", S. J. Edmonds.

Previous Australian record.—QUEENSLAND: Low Isles (Monro 1931).

Description

The trunk of the specimens is somewhat spindle-shaped, 1·5-2·2 cm long and 4-7 mm wide in the mid body region. The colour of the trunk is pale straw, becoming yellow near the shields, which are dark brown in colour. The anterior shield, with a maximum width of about 3 mm, is oval in shape and consists of a number of polygonal plates to which are attached some white calcareous particles. No furrows were observed on its surface. The posterior shield is more knob-like in shape and 3-3·5 mm in diameter. A slender introvert nearly as long as the trunk bears anteriorly 10 short, pale tentacles and 20-44 rows of yellowish hooks with double points (Fig. 19). Between the rows of hooks are rows of very small, spine-like papillae, possibly the "Ausmündungs-papillen der Hautkörper" of Selenka (Selenka, de Man, and Bülow, 1883, p. 119). The rest of the introvert is covered with densely packed, dark brown, irregularly arranged and directed thorns or spines. A clear, ring-like area in the middle of the introvert possessing neither spines nor hooks, as described for the species by Selenka, was not observed.

The body wall bears numerous papillae which are largest (0·4 mm) and most prominent near the shields. Polygonal plates, like those which make up the surface of the papillae, also cover the body surface between the papillae. The longitudinal musculature is grouped into about 20 anastomosing bundles which are clearly visible externally. There are 2 stout retractor muscles which fuse. They arise from muscles 2-6 (1-6). The intestine is held firm by a spindle muscle attached to the body wall anteriorly and posteriorly. A contractile vessel without papillae runs along the dorsal surface of the oesophagus. A small caecum is attached to the rectum but no fastening muscle was found. The nephridia are long, reaching to the base of the retractors, and are fixed for about two-thirds of their length.

Systematic position

The identification of these specimens depends on: (i) the fact that the longitudinal musculature is grouped into bundles; (ii) the structure of the introvert hooks. The longitudinal musculature of *A. hartmeyeri* is continuous and the hooks of *A. klunzingeri* and *A. cumingii* are single-pointed.

Distribution.—In Australia, Great Barrier Reef, Qld. Other records: Mauritius, Java, Loyalty Is., Maldive and Laccadive Is., the Malay Peninsula, and New Guinea. Sato (1939, p. 426) says that this species is "one of the commonest sipunculids found in the tropical seas of the Pacific Ocean".

ASPIDOSIPHON KLUNZINGERI Selenka & de Man

Fig. 20; Plate 3, Fig. 1

Aspidosiphon klunzingeri Selenka & de Man, in Selenka, de Man, and Bülow, 1883, p. 115.

Specimens examined, 2.—QUEENSLAND: Low Isles, sand flat, east of lighthouse, 17.viii.1954, Prof. W. Stephenson (Univ. of Qld.); Heron I., "in dead coral", 12.viii.1955, S. J. Edmonds.

Previous Australian record.—QUEENSLAND: Low Isles (Monro 1931).

Distribution

The trunk of the larger specimen is very pale brown in colour, 4·0 cm long, and curved ventrally to some extent. Its width is fairly uniform (4-4·5 mm). The introvert is slender, thin-walled, and about 4·5 cm long. Anteriorly it bears 65 rows of single-pointed hooks (Fig. 20). Very small papillae, about 0·01 mm in diameter, lie between the rows of hooks. Immediately posterior to these hooks the introvert is armed with numerous small brown spines, irregularly placed and directed. The 2 shields are darker in colour than the trunk. The posterior one is slightly conical in shape, 3·5 mm in diameter, and showing about 27 radial furrows. The anterior shield is elliptical in outline and shows about 10-15 furrows which radiate like the ribs of a fan.

The body wall is thick. Papillae, consisting of numerous polygonal plates, cover the surface of the trunk and are largest (0·2-0·35 mm) anteriorly. The longitudinal musculature is grouped into about 26 anastomosing bundles. There is a single introvert retractor which could be described as arising from 2 very short roots, or from 1 single root split just above the nerve cord. The retractors, spanning muscles 1-8 on each side of the nerve cord, arise in the posterior third of the body wall well above the caudal shield. The intestine is very thin-walled and in the specimen dissected filled with coral fragments. A stout spindle muscle is fixed anteriorly to the anal shield and posteriorly to the caudal shield. The rectum is long and does not appear to bear a caecum. The nephridia are long and free and open to the exterior between muscles 4 and 5. No intestinal fastener could be found.

Systematic position

These specimens fall into the group of *Aspidosiphon* in which the longitudinal muscles are grouped into separate bundles. The hooks on the introvert, unlike those of *A. steenstrupii*, possess only one point. The specimens correspond closely with Selenka's description of *A. klunzingeri* and are being identified as such. Selenka's specimens, however, possess: (i) only one retractor which spans 20 longitudinal muscles; (ii) "am Rectum ein grösser an beiden Seiten vielfach gelappter Blind sack", not present in the two specimens from the Great Barrier Reef. *A. cumingii* Baird, a closely related species, bears numerous rectal appendages.

Distribution.—In Australia, the Great Barrier Reef. Other records: South Africa, Amboina, Philippine Is., the Red Sea, Funafuti, New Britain, Moluccas, and Loyalty Is.

ASPIDOSIPHON CUMINGII Baird

Aspidosiphon cumingii Baird, 1868, p. 102.
Aspidosiphon cumingii Selenka & de Man, in Selenka, de Man, and Bülow, 1883, p. 113.

Australian record.—QUEENSLAND: Low Isles (Monro 1931).

Remarks.—In this species the longitudinal musculature is separated into bundles, the introvert hooks have only one point, and numerous rectal appendages are present.

Genus CLEOSIPHON Grube

Diagnosis

A rounded cap-like structure made up of numerous plates present at the anterior extremity of the trunk. No posterior shield. Introvert arises from centre of anterior rounded cap. Longitudinal musculature is continuous and not grouped into separate bundles. Anterior region of introvert bears hooks. Single retractor muscle present.

Type, *Loxosiphon aspergillum* Quatrefages (Quatrefages 1865, p. 605; Grube 1867, pp. 48-9).

CLEOSIPHON ASPERGILLUM (Quatrefages)

Fig. 21; Plate 3, Fig. 2

Loxosiphon aspergillum Quatrefages, 1865, p. 605.
Cleosiphon aspergillum Grube, 1867, p. 48.

Specimens examined, 46.—QUEENSLAND: Heron I., 27.viii.1950, "in a piece of coral", Prof. W. Stephenson (Univ. of Qld.) (4 spec.); Heron I., 15.viii.1955, "boring in dead coral", S. J. Edmonds (35 spec.); Heron I., 23.viii.1948, Dr. J. Mackerras (7 spec.).

Previous Australian record.—QUEENSLAND: Low Isles (Monro 1931).

Description

The specimens are almost cylindrical in shape and usually light brown or buff-coloured both when alive and in the preserved condition. Some specimens when alive are pink to red. The body wall is thin and almost transparent. The length of the trunk is 15-41 mm and the maximum width 3-5 mm. The most striking feature of the animal is that the trunk bears anteriorly a white, calcareous, rounded structure or knob 2-5 mm in diameter. It is composed of small, white, polygonal plates of 4-6 sides arranged in spiral rows. Each plate usually possesses at least 1 small brown pore. At first sight the structure resembles a pineapple slightly flattened. The plates anteriorly are larger in size and less regular in shape.

A slender introvert which arises from the centre of the anterior knob is about as long as the trunk and is armed with rows of double-pointed hooks. These hooks, some of which are shown in Figure 21, correspond closely with those of *C. aspergillum* shown in Figure 216 of Selenka's monograph (Selenka, de Man, and Bülow 1883).

The longitudinal musculature of the body wall is continuous and not divided into bundles. Although the trunk looks smooth, numerous small, buff-coloured papillae are present on the body wall. They are largest and most densely distributed at the anterior and posterior regions of the trunk. The largest are about 0·2 mm in diameter.

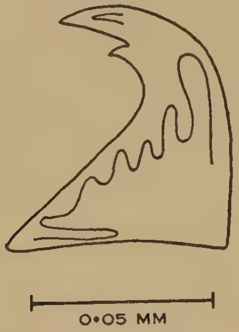

Fig. 21.—*Cleosiphon aspergillum.* Introvert hook.

There is a single long retractor which bifurcates posteriorly into 2 short roots. A fastening muscle arises from the body wall, passes between the 2 roots of the retractor muscle, and connects with the posterior intestine. The nephridia are dark in colour and long, extending to the base of the retractors. They are fixed to the body wall for their entire length. In most specimens the nephridia and the ventral nerve cord can be seen through the body wall. No intestinal caecum was discerned in the specimens dissected.

Systematic position

The identification of this species depends on the presence of a rounded, cap-like knob anteriorly and the structure of the hooks found on the introvert.

Distribution.—This species occurs in coral formations. In Australia, on the Great Barrier Reef, Qld. Other records: Japan, the Philippines, Java, Samoa, Ceylon, Maldive and Laccadive Is., the Red Sea, Mauritius, and Zanzibar.

KEYS TO GENERA AND SPECIES

KEY TO GENERA OF AUSTRALIAN SIPUNCULOIDEA

1. No horny or calcareous shield or cone at the anterior end of the trunk; enlarged horny papillae or tubercles, however, may be present in the anal region 3
2. A specialized shield or cone present at the anterior end of the trunk 13, 14
3. Longitudinal muscle layer of body wall divided into separate bundles 5
4. Longitudinal muscle layer of body wall continuous and not divided into separate bundles 11, 12

5. Body of adult long and cylindrical; surface devoid of prominent papillae 7
6. Body of adult not long and cylindrical but bottle-, flask-, or pear-shaped; skin covered with papillae which may become large and prominent or tubercular in anal region and at posterior extremity; tentacles few to numerous and arranged in a circle (interrupted dorsally), situated dorsal to mouth; usually 4 retractors ......*Phascolosoma* Leuckart
7. Introvert with numerous triangular, scale-like lappets directed posteriorly; a flat tentacular fold surrounds oral disc 9
8. No scale-like lappets on the introvert; skin of trunk not divided into rectangular furrows; tentacles usually finger-like; 4 retractors; spindle muscle arises anteriorly from at least 3 roots and is fastened posteriorly to the body wall ....*Siphonosoma* Spengel (see Edmonds 1955, p. 89)
9. Anal aperture posterior to nephridial apertures; 4 retractors; spindle muscle arises anterior to anal aperture and not fixed posteriorly ....*Sipunculus* Linnaeus (see Edmonds 1955, p. 82)
10. Anal aperture anterior to nephridial apertures; 4 introvert retractors and 2 small protractor muscles arising in front of anus ....*Xenosiphon* Fisher (see Edmonds 1955, p. 87)
11. Tentacles large and bushy (dendritic) arising from 4-8 stems; usually 2 retractors; contractile vessel with villi ....*Dendrostomum* Grube
12. Tentacles relatively small, finger- or thread-like, few to many ....*Golfingia* Lankester
13. Horny or calcareous shield-like structure present at both ends of trunk; introvert arises on ventral side of anterior shield; longitudinal musculature continuous or separated into separate bundles ....*Aspidosiphon* Diesing
14. A round cap-like structure made of calcareous plates present at anterior end of trunk; introvert arises from centre of cap; no posterior shield ....*Cleosiphon* Grube

This key is based on keys drawn up by Sato (1939) and Fisher (1952). No species belonging to the following genera have been reported in Australia: *Siphonomecus* Fisher, 1947; *Siphonides* Fisher, 1952; *Phascolion* Theel, 1875; *Onchnesoma* Koren & Danielssen, 1875; *Lithacrosiphon* Shipley, 1902.

KEY TO SPECIES OF AUSTRALIAN SIPUNCULOIDEA

Genus SIPUNCULUS

1. Numerous, brittle thread-like processes arise from the brain; 27-30 longitudinal muscles; racemose glands ("büschelförmigen Körper") on rectum; rectal diverticulum; 2 contractile vessels with villi ....*S. angasi* Baird
2. No processes arising from brain; 27-30 longitudinal muscles; according to Keferstein no racemose glands, no diverticulum, and 1 contractile vessel ......*S. robustus* Keferstein

Genus XENOSIPHON

1. Longitudinal muscles 27-30; nephridia short and stout; rectum long; coelomic canals lie between longitudinal muscles ....*X. mundanum* (Selenka & de Man)

Genus SIPHONOSOMA

1. Transverse, crescentic shaped dissepiments present in coelomic cavity; no hooks on introvert; 18-20 longitudinal muscles ....*S. cumanense* (Keferstein)
2. No transverse dissepiments arise from coelomic wall 3, 4
3. Numerous, finger-like villi or caeca arise from the rectum; large species; 23-26 longitudinal muscles; introvert hooks present (?) ....*S. vastum* (Selenka & de Man)
4. Single rectal caecum; 15-20 longitudinal muscles; introvert hooks present .... *S. australe* (Keferstein)

Genus PHASCOLOSOMA

1. Only 4 rows of introvert hooks .... *P. nigritorquatum* Sluiter
2. More than 4 rows of hooks 3, 4
3. Posteriorly directed, spine-like papillae present on introvert and posterior extremity of trunk; hooks sharply bent; a slender species .... *P. dentigerum* (Selenka & de Man)
4. No posteriorly directed spine-like papillae on introvert and posterior extremity of trunk . . 5, 6
5. Papillae on trunk consist of large polygonal plates 7, 8
6. Papillae on trunk consist of numerous small plates of approximately equal size 9, 10
7. Papillae surrounded basally with a ring of darker plates; plates or platelets found on trunk between the papillae; 4 retractors arise from middle of trunk and remain separate for a considerable length .... *P. tasmaniense* (Fischer)
8. No row of darker plates at base of papillae; no plates on body between papillae; 4 short retractors arise in posterior third of body close to ventral nerve cord and fuse to form 1 large retractor; circular muscle tends to form separate bundles; clear streak of hook expands considerably at base .... *P. lurco* (Selenka & de Man)
9. Nephridia very long, reaching to posterior extremity of trunk and fixed for their entire length to the body wall .... *P. pacificum* Keferstein
10. Nephridia do not reach to posterior extremity of trunk and are not fixed for their entire length to the body wall 11, 12
11. Papillae on trunk approximately equal in size; no darkly pigmented band on introvert; uniformly dark-coloured hook with relatively wide base ...... *P. noduliferum* Stimpson
12. Papillae on trunk differ considerably in size and distribution, being largest and most densely packed at the anterior and usually the posterior extremities 13, 14
13. Introvert hooks with 2 clear areas, one triangular and the other crescentic; colour of specimens usually pale straw; papillae may be reduced on posterior surface of trunk .... *P. heronis*, sp. nov.
14. Introvert with 1 (triangular) clear area or no clear area alongside of streak 15, 16
15. Clear streak expanded very much basally .... *P. nigrescens* Keferstein
16. Clear streak not expanded very much basally 17, 18
17. Clear streak comparatively narrow .... *P. rottnesti*, sp. nov.
18. Clear streak comparatively wide .... *P. dunwichi*, sp. nov.

Genus DENDROSTOMUM

1. Trunk flask or pyriform in shape 3, 4
2. Trunk long (16-28 cm), slender and almost cylindrical; no introvert hooks; tentacles plumose and flecked with dark brown; rectum very long .... *D. dehamatum* Kesteven
3. Large species (5-9 cm); tentacles flecked brown or purple and relatively small; no introvert hooks; yellow-brown band surrounds introvert near its middle .... *D. cymodoceae*, sp. nov.
4. Smaller species (2-2·5 cm); tentacles without flecking and relatively large; dark blue band surrounds introvert near its middle; without introvert hooks (?) .... *D. signifer* Selenka & de Man

Genus GOLFINGIA

1. Two introvert retractors 3, 4
2. Four introvert retractors 7
3. Introvert hooks present 5, 6
4. No introvert hooks present; nephridiopores anterior to anal aperture; 1 fixing muscle . . .. *G. semperi* (Selenka & de Man)
5. Rectal diverticulum present; 4 fixing muscles .... *G. schuttei* (Augener)

6. No rectal diverticulum present; 3 fixing muscles .... *G. pellucida* (Keferstein)
7. Introvert hooks present 9, 10
8. Introvert hooks absent; skin smooth and pale yellow in colour; anterior region of introvert usually swollen .... *G. margaritacea* (Sars) *adelaidensis*, subsp. nov.
9. Hooks bear accessory teeth at base; relatively long introvert; 8 tentacles; 1 fixing muscle .. .. *G. misakiana* (Ikeda)
10. Hooks without accessory teeth; 3 fixing muscles; numerous fine white tentacles .... *G. vulgaris* (Blainville) *queenslandensis*, subsp. nov.

Genus Aspidosiphon

1. Longitudinal musculature divided into separate bundles visible externally **3, 4**
2. Longitudinal musculature continuous and not divided into bundles; introvert hooks with double points; circular musculature tends to be grouped into bundles (noticed on dissection) .... *A. hartmeyeri* Fischer
3. Introvert hooks with single points 5, 6
4. Introvert hooks with double points; introvert retractor arises from 2 short roots; no fixing muscle .... *A. steenstrupii* Diesing
5. Strong fixing muscle present; rectum with numerous appendages or villi .. *A. cumingii* Baird
6. No fixing muscles; rectum without numerous villi ...... *A. klunzingeri* Selenka & de Man

Genus Cleosiphon

1. Hooks with double points .... *C. aspergillum* (Quatrefages)

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EXPLANATION OF PLATES 1-3

PLATE 1

Fig. 1.—*Dendrostomum dehamatum.* Specimen from Balmoral, N.S.W. Natural size.

Fig. 2.—*Dendrostomum signifer.* Specimen from Yeppoon, Qld. × 4·1.

PLATE 2

Fig. 1.—*Dendrostomum cymodoceae.* Specimen from Aldinga, S.A. × 1·25.

Fig. 2.—*Golfingia margaritacea adelaidensis.* Specimen from Aldinga, S.A. × 1·25.

PLATE 3

Fig. 1.—*Aspidosiphon klunzingeri.* Specimen from Low Isles, Qld. × 2·75.

Fig. 2.—*Cleosiphon aspergillum.* Specimen from Heron I., Qld. × 5·4.

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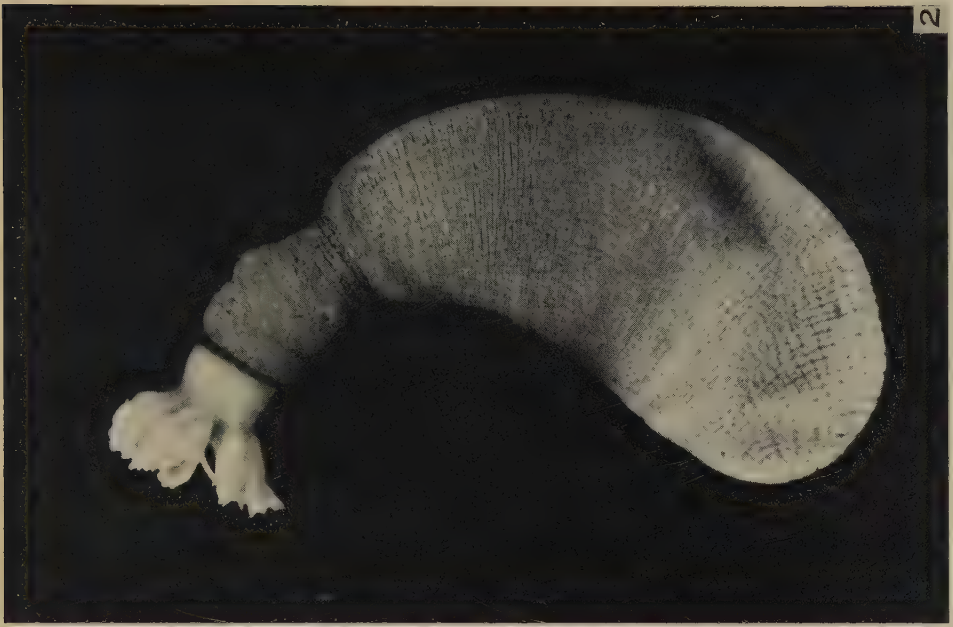

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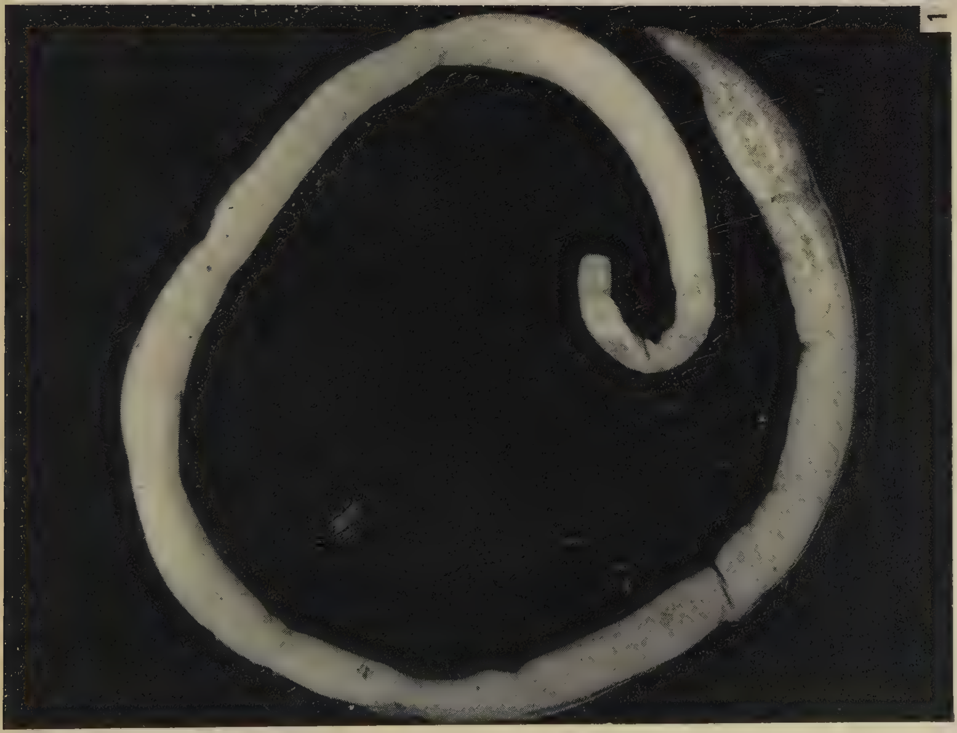

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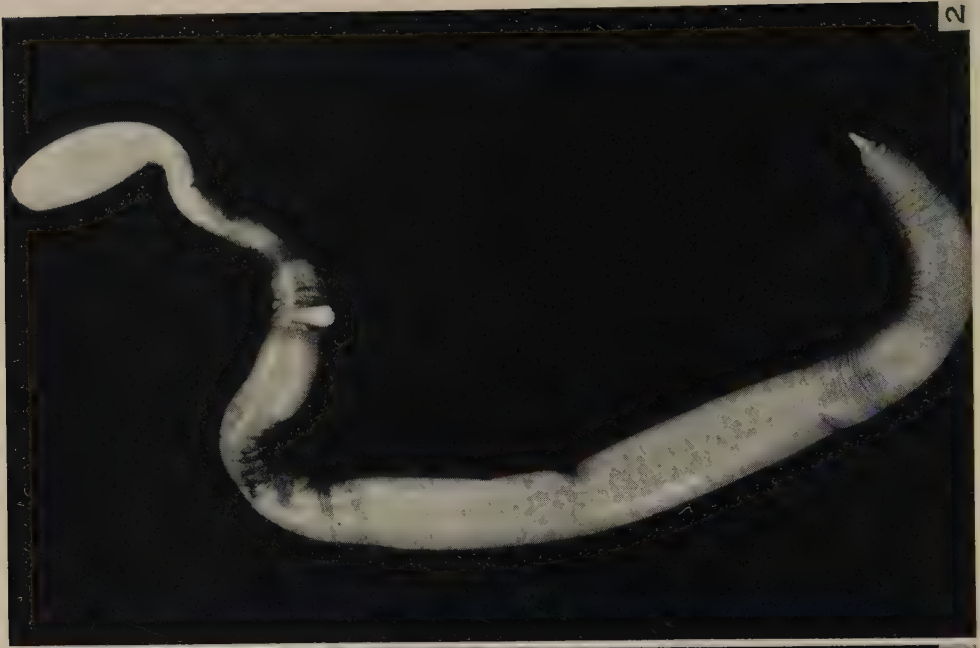

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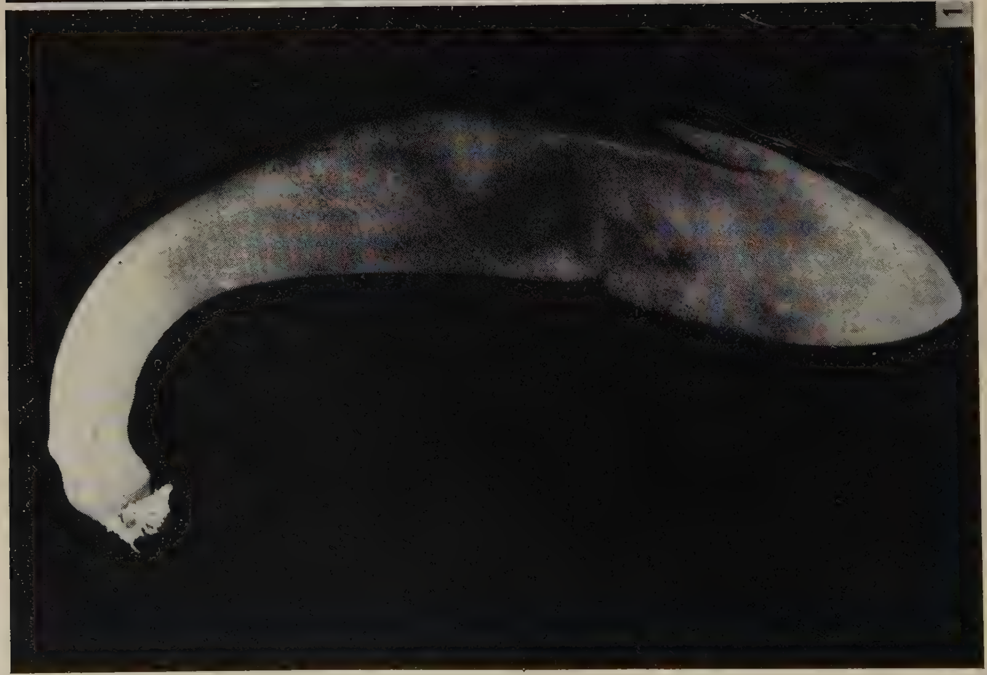

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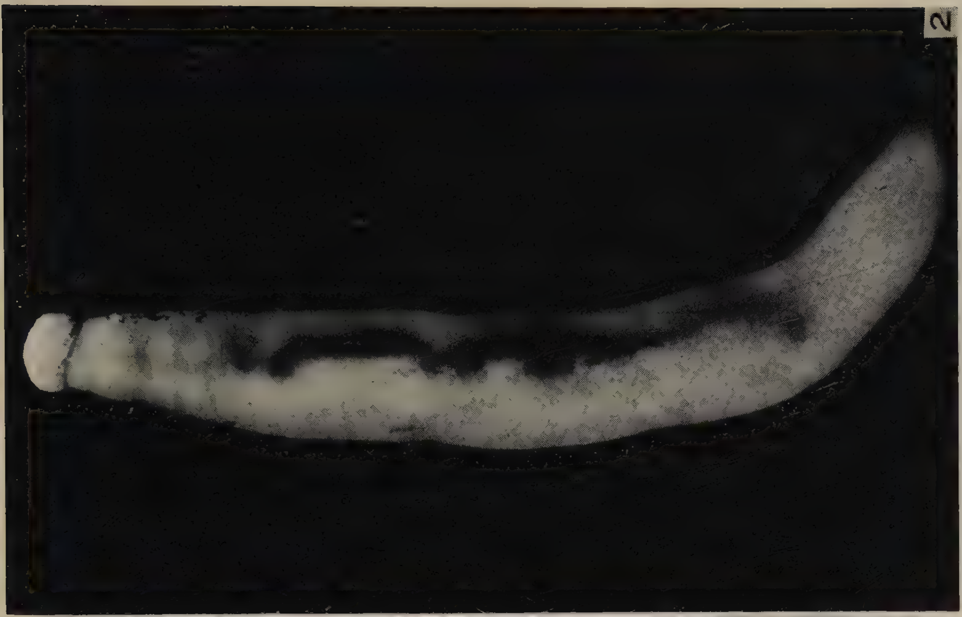

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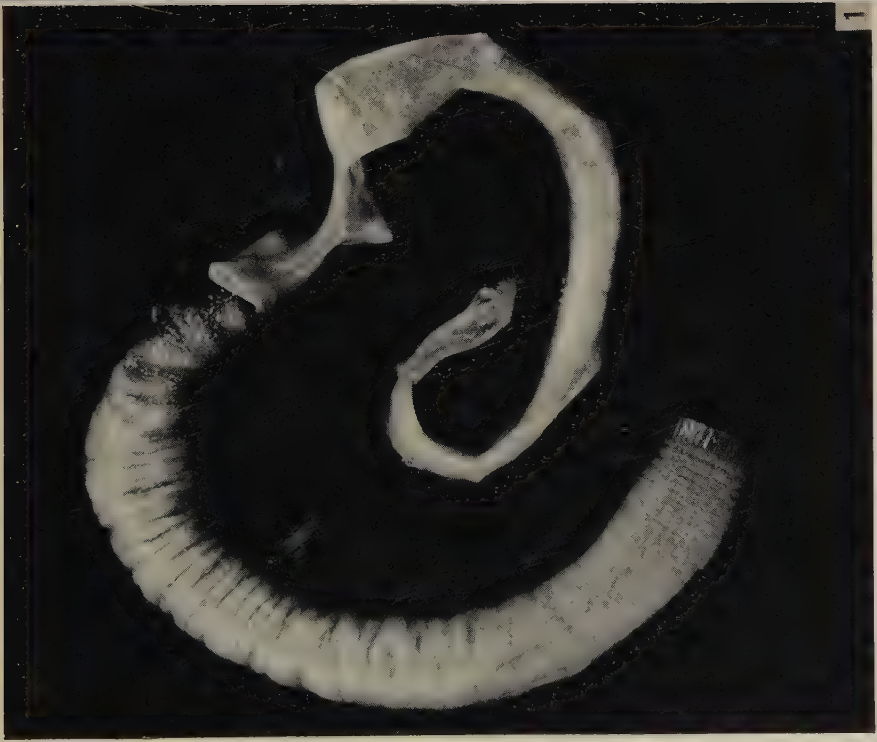

1

THE ECOLOGY AND DISTRIBUTION OF INTERTIDAL ORGANISMS ON CERTAIN ISLANDS OFF THE QUEENSLAND COAST

By R. ENDEAN,* W. STEPHENSON,* and R. KENNY*

[*Manuscript received April* 13, 1956]

Summary

The species composition and general ecology of intertidal organisms present at Heron Island, a coral cay in the Capricorn Group, are recorded in this paper. It was found that the general zonation picture on this Great Barrier Reef island differed markedly from that found previously at localities on the Queensland mainland (Endean, Kenny, and Stephenson 1956). In particular the mainland upper barnacle (*Chthamalus*) zone was not represented at Heron I., and the species forming the mainland lower barnacle zone (*Tetraclita squamosa* (Bruguière)) was replaced by a different species (*Tetraclita vitiata* Darwin). Also the characteristic algal zone of mainland localities was replaced by a lithothamnion-zoanthid-coral zone.

In order to investigate the possibility of a gradual transition from the mainland type zonation to that found on the Great Barrier Reef, as exemplified by Heron I. zonation, the species composition and general ecology of intertidal organisms inhabiting a series of continental islands lying off the Queensland coast between lat. 16° and 22° S. were investigated. The fauna of these islands was found to be closely allied to that of the mainland. There was, however, an intrusion of corals and zoanthids on the more exposed of the islands visited which lie between lat. 20° and 22° S., and also on the more northerly of the islands visited. The biogeographical implications of these findings are discussed, and it is noted that the results of the present investigation support the contention of Whitley (1932) that a longitudinal division of the Queensland marine fauna into "Solanderian" and "Banksian" elements is warranted.

Accounts are also given of the major environmental factors that might affect specific composition and zonation patterns at the localities investigated. Analyses of these have given much information on the general ecology and distribution of many Queensland intertidal species. This information is discussed. Of particular interest was the finding that the Peronian barnacle *Tetraclita rosea* (Krauss) has extended its range to the north of the biogeographical boundary situated near lat. 25° S. by colonizing the more exposed of the continental islands.

I. INTRODUCTION

In Queensland attention has been concentrated on the fauna of the coral islands. This is due largely to the popular appeal of the Great Barrier Reef, and several books dealing partially or wholly with the fauna of this region have been published (Saville-Kent 1893; Banfield 1908, 1911, 1918; Yonge 1930; Roughley 1936; Dakin 1950; Serventy 1955). Also several scientific papers deal with ecological aspects of the coral islands, particularly with their associated reef flats (Hedley 1906; Hedley and Taylor 1908; Mayer 1918; Musgrave 1926; Stephenson *et al.* 1931; Manton and Stephenson 1935; Salter 1954).

On the other hand the rocky or continental islands have received scant treatment from ecologists. Rainford (1925) commented on the destruction of the Whit-

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sunday Group fringing reefs caused by the 1918 cyclone, and Guiler (1952) made brief reference to zonation on West Molle I.

In a previous paper (Endean, Kenny, and Stephenson 1956) the zonation and distribution of organisms along a thousand miles of the Queensland coast were discussed. Subsequently a cursory examination of comparable habitats on Heron I., a coral cay in the Capricorn Group, gave a picture which differed markedly from that obtained on the mainland. It was decided to investigate further the faunistic composition and zonation at Heron I. with a view to ascertaining the reasons for the differences observed. Also it was considered that an examination of faunistic composition and zonation on the continental islands might throw light both on the Heron I. picture and on some of the problems arising from the mainland studies. In particular such an examination should give some indication of whether there is a west-east transition in the Queensland littoral fauna as mainland waters grade into the waters of the Great Barrier Reef.

II. Sites of Investigation and Methods Used

Several islands in the Capricorn and Bunker Groups and also Lady Elliott I. have been visited by one or more of the authors. Heron I. in the Capricorn Group was selected as typical, and traverses were made by all three authors in January 1954.

In May and June 1954, one of the authors (W.S.) paid a brief visit during a supply voyage by the Commonwealth Lighthouse Service Steamer *Cape Leeuwin* to each of the following islands: High Peak I., Pine I., Flat Top I., Bailey I., Coppersmith I., Dent I., Bay Rock I., Kent I. (North Barnard Is.), and Fitzroy I. Magnetic I. was visited by all three authors in August 1953. The localities mentioned are shown in Figure 1, and brief descriptions of the sites of the traverses made are given in Appendix I.

At Heron I. and Magnetic I. methods utilized in a previous investigation were followed (see Endean, Kenny, and Stephenson 1956). Where only one of the authors was present the same principles were adhered to, but measurements of actual heights of zones were not possible and were replaced by estimations of effective tidal levels.

III. General Account of Islands off the Queensland Coast

(a) *Continental Islands*

Many of the islands off the east Queensland coast are termed continental islands because their disposition and geological structure indicate that they are portions of the continental land mass cut off by submergence from the present mainland (David 1914; Jardine 1925; Richards and Hedley 1925; Steers 1929, 1937). They lie in the channel between the Great Barrier Reef and the mainland and, although some are relatively isolated, the majority are arranged in clusters. The most southerly of these archipelagoes lies in the Port Curtis–Keppel Bay region (see Fig. 1).

Many islands of various sizes comprise the Northumberland Isles, the Cumberland Is., and the Hinchinbrook Group. Other smaller island groups occur between

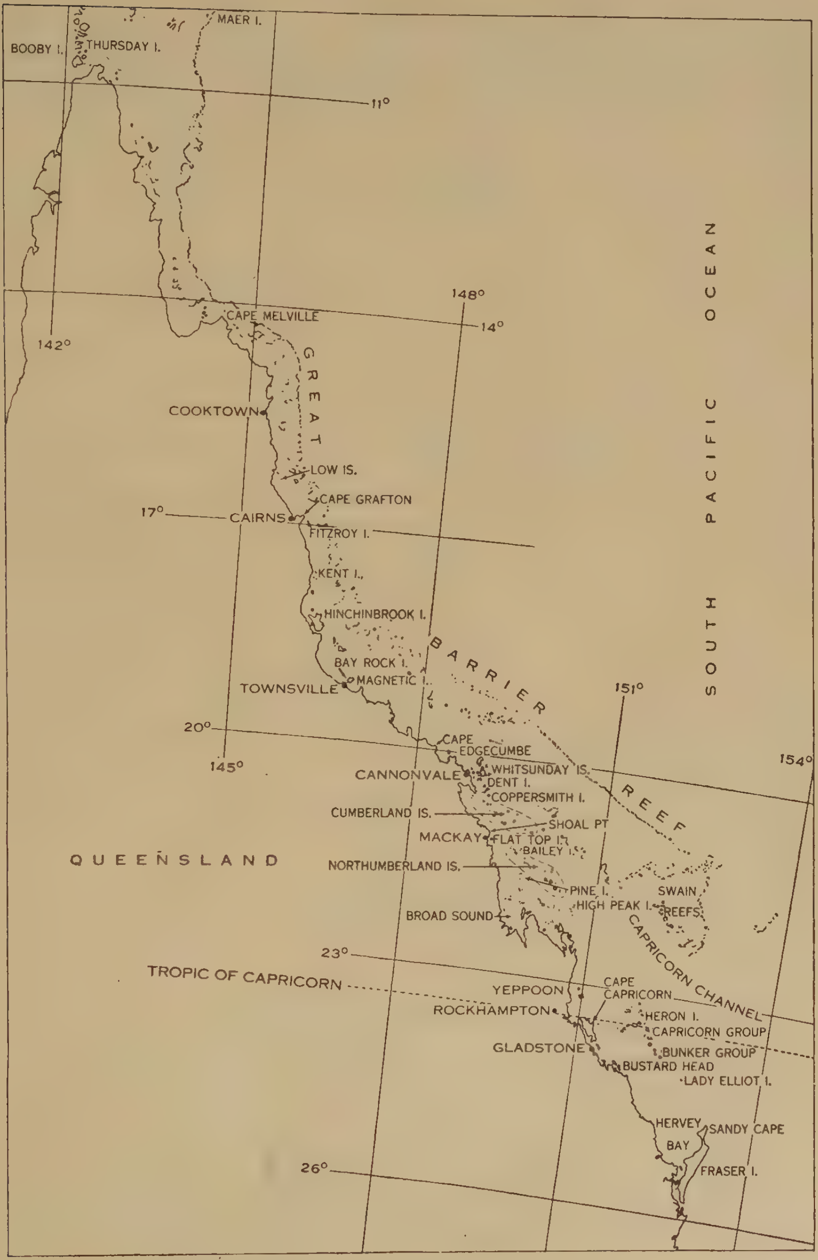
BOOBY I.
THURSDAY I.
MAER I.
11°
142°
148°
14°
CAPE MELVILLE
GREAT
COOKTOWN
LOW IS.
CAPE GRAFTON
17°
CAIRNS
FITZROY I.
KENT I.
HINCHINBROOK I.
BARRIER
BAY ROCK I.
MAGNETIC I.
TOWNSVILLE
151°
20°
145°
CAPE EDGECUMBE
CANNONVALE
WHITSUNDAY IS.
DENT I.
COPPERSMITH I.
REEF
154°
CUMBERLAND IS.
SHOAL PT
MACKAY
FLAT TOP I.
BAILEY I.
QUEENSLAND
NORTHUMBERLAND IS.
PINE I.
SWAIN REEFS
HIGH PEAK I.
BROAD SOUND
CAPRICORN CHANNEL
23°
TROPIC OF CAPRICORN
YEPPOON
CAPE CAPRICORN
ROCKHAMPTON
HERON I.
CAPRICORN GROUP
GLADSTONE
BUNKER GROUP
BUSTARD HEAD
LADY ELLIOT I.
HERVEY BAY
SANDY CAPE
26°
FRASER I.
SOUTH PACIFIC OCEAN

Fig. 1.—Map of Queensland showing localities and geographical features mentioned in the text. Port Curtis is the area of water between Gladstone and the islands immediately offshore; Keppel Bay the area of water between Rockhampton and the island on which Cape Capricorn is situated.

Hinchinbrook I. and Cape York. Distances of all these islands from the mainland vary greatly (from approximately 3 to 60 miles).

Geological structure, and the degree of wave action to which each is subject, have influenced the contours of these islands. Many have precipitous sides and plunge sheer into the water of the channel, which varies in depth between 10 and 20 fm. On the other hand some have fringing reefs, whilst yet others possess an alluvial fringe. Some have high peaks (e.g. Hinchinbrook I., which rises to 3000 ft), others are mere mounds of rock. Many continental islands are wooded but some bear only stunted shrubs.

(*b*) *Coral Islands*

Other islands found off the Queensland coast have no mainland bedrock and are formed principally of calcareous materials. They vary in structure, and several classifications have been proposed (Steers 1929, 1937; Spender 1930; Fairbridge 1950).

Heron I. in the Capricorn Group is a typical vegetated sand cay, consisting essentially of coral sand (pulverized coral fragments) heaped up on the lee side of an atoll-like reef platform. The sand of the cay has, in places, become lithified, resulting in the formation of so-called "beach rock" (Jukes 1847), which is exposed between tide marks at certain regions and confers on the structure a certain degree of stability.

The reef crest which is exposed at low tide is in the form of an ellipse, the principal axis of which runs east to west. Fragments of dead coral, chiefly branching and bracket-shaped *Acropora* spp., are heaped together on the crest. A rim of large boulders of dead coral (termed negro-heads) delineates the reef crest at higher levels of the tide. Hedley (1906) regarded the "negro-heads" as erratics that had been lifted from deeper water and cast up on the reef crest by storms—a view that has been shared by subsequent authors.

Apparently the negro-heads are transient elements, and Hedley (1906) estimated that the negro-heads at Mast Head I. in the Capricorn Group lose by erosion and solution a crust 2 in. thick in 4 or 5 years.

The reef crest encircles a reef flat and a lagoon* of variable depth. At low tide the waters which are dammed up behind the reef crest escape to the open sea via numerous drainage channels of varying size. Out from the western edge of the reef the depth of water varies from 15 to 20 fm, and Heron I. itself is only about 20 miles from the 100-fm line.

Low Isles provides an example of a more complex type of coral island. It consists of two entities: a mangrove shingle island on the weather side and a coral cay on the lee side. Accounts of its general structure have been given by Steers (1929), Spender (1930), Stephenson *et al.* (1931), Fairbridge and Teichert (1947, 1948), and Fairbridge (1950). Its detailed ecology has been studied by T. A. Stephenson *et al.* (1931), and by W. Stephenson, Endean, and Bennett (unpublished data), and brief reference is made to this at a later stage.

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* The lagoon is considered to be that part of the reef flat which is not exposed at L.W.S.

IV. Physico-chemical Factors

The principal factors likely to affect zonation and faunistic assemblages in Queensland waters were discussed previously (Endean, Kenny, and Stephenson 1956). Additional data pertaining to specific island localities are given below.

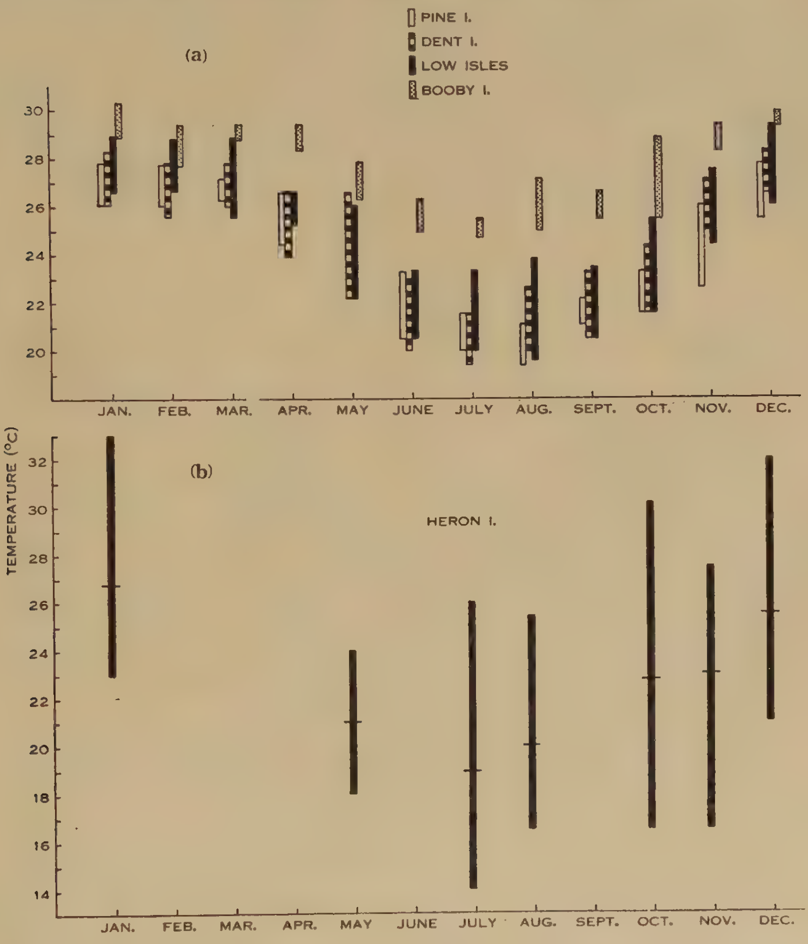

Fig. 2.—(*a*) Monthly range of sea temperature at four Queensland islands. Drawn from data obtained from the Brisbane office of the Marine Branch, Commonwealth Department of Shipping and Transport. Records comprised 15 or more observations per month from August 1952 to August 1954. (*b*) Sea temperature range on the reef flat at Heron I. for certain months; the horizontal bars denote mean temperature. Records comprise 15 or more observations for months shown taken during 1954 and 1955.

(*a*) *Sea Temperature*

Data from four island stations were provided by the Brisbane office of the Marine Branch, Commonwealth Department of Shipping and Transport, and are summarized in Figure 2(*a*). Temperatures were in accord with expectations based on data compiled by the Royal Netherlands Meteorological Institute (1949), which were previously summarized. Apparently there are no intrusions of markedly colder or warmer bodies of water inside the Great Barrier Reef area but there is merely a uniform variation with latitude.

Water temperatures over the reef flat at Heron I. near the region where a traverse was made have been compiled from records kept by various members of the Department of Zoology, University of Queensland, and are summarized in Figure 2(*b*). Although the mean temperatures fall within the expected range for the locality a wide monthly temperature range will be noted. This is due primarily to the shallow depths and wide expanse of waters on the reef flat. Consequently temperatures there are greatly influenced by terrestrial conditions, particularly at low water.

(*b*) *Wave Action*

(i) *Continental Islands.*—The degree of wave action at a particular island locality is affected by three chief factors:

(1) *Latitude.*—The southerly islands are exposed to oceanic swell which enters through the Capricorn Channel. Also the southern reefs of the Great Barrier Reef do not form a continuous chain as they do further north and hence are not such an effective barrier against oceanic swell.

(2) *Prevailing Winds.*—These are the south-easterly trades. Normally the south-easterly sides of the islands are the most exposed and, because these trade winds have an easterly component, the greater the distance from the protective Barrier Reef the greater is the fetch of the waves within the channel. It should be noted that south of Cape Grafton the Barrier Reefs diverge noticeably from the mainland.

(3) *Local Protection.*—Fringing and platform reefs, and the proximity of other islands and of projecting mainland capes and prominences, influence wave action at any specific island locality.

Analysis of the above factors at each locality visited, and discussion with lighthouse keepers, fishermen, and officials of the Queensland Department of Harbours and Marine, allow the islands to be classified as follows with respect to wave action:

Moderate to severe.—High Peak I.

Moderate.—Bailey I., Coppersmith I.

Slight.—Pine I., Flat Top I., Dent I., Magnetic I., Bay Rock I., Kent I., Fitzroy I.

(ii) *Heron Island.*—The cay is protected by the reef crest from oceanic swell. At high tide, however, waves may cross the reef flat and impinge on the cay. The amplitudes of such waves are small because of the shallowness of the water. On the other hand the reef crest is fully exposed to oceanic swell and wind-blown waves. Consequently there is usually surf in this region. Neighbouring reefs and islands afford some protection when the wind is blowing from certain quarters.

V. Zonation and Faunistic Composition at Heron Island

(*a*) *Habitats Investigated*

Habitats at Heron I. comparable to rocky mainland localities were the intertidal beach rock of the cay, and the negro-heads and semi-consolidated coral rubble of the reef crest (see Fig. 3(*a*)).

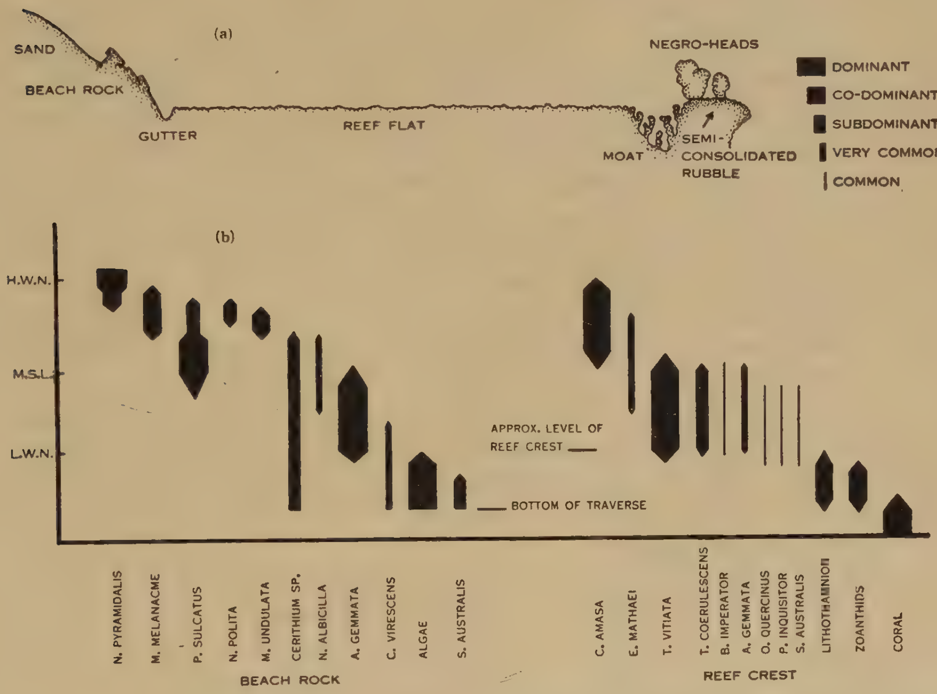

Fig. 3.—(*a*) Sectional diagram of locality where traverses were carried out at Heron I. Vertical scale greatly exaggerated. (*b*) Diagrammatic representation of zonation of organisms on beach rock and reef crest at Heron I.

(*b*) *Results of Ecological Investigations*

(i) *Intertidal Beach Rock*.—This was investigated at its position of best development on the southern side of the island. The zonation and relative abundance of the organisms encountered are summarized in Figure 3(*b*). Five main zones were in evidence:

(1) *Upper Littorinid Zone*.—*Nodilittorina pyramidalis*,* typically found above H.W.S. on the mainland, was sparsely represented and extended down to well below H.W.N.†

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* A systematic list of species with authors is given in Appendix II.

† Abbreviations used for tidal heights in this paper are: mean low water spring (L.W.S.), mean low water neap (L.W.N.), mean low water (M.L.W.), mean sea-level (M.S.L.), mean high water (M.H.W.), mean high water neap (H.W.N.), and mean high water spring (H.W.S.).

(2) *Lower Littorinid Zone.*—*Melaraphe melanacme* and *Melaraphe undulata* were co-dominants in this zone, which extended from just below H.W.N. to a point about half-way between H.W.N. and M.S.L. The zone was therefore much lower than on the mainland. Also *M. melanacme* was much more sparsely represented than on the mainland, but *M. undulata* was commoner than it usually is at most mainland localities.

(3) Planaxis *Zone.*—In the region extending from about half-way between H.W.N. and M.S.L. to just below M.S.L. *Planaxis sulcatus* was a dominant. On the mainland, *P. sulcatus*, although common, is never a dominant, and the region between H.W.N. and M.S.L. is dominated by the oyster *Crassostrea amasa*. At Heron I. specimens of *P. sulcatus* were speckled black and white, in contrast with the uniformly dark mainland form.

(4) *Chiton Zone.*—*Acanthozostera gemmata*, which attains a length of about 14 cm, was a dominant from just below M.S.L. to about L.W.N. On the mainland it is occasionally common but the barnacle *Tetraclita squamosa* dominates the equivalent zone.

(5) *Algal Zone.*—From L.W.N. to the bottom of the traverse (about M.L.W.) algae (mostly *Enteromorpha* spp.) dominated. Different algal species form the corresponding algal zone on the mainland.

Other organisms noted were: *Nerita polita*, *N. albicilla*, *Siphonaria australis*, an unidentified species of *Cerithium*, *Clibanarius virescens*, amphipods, and grapsid crabs. The fauna of the beach rock is remarkably sparse as regards both variety and density of species compared with mainland rocks. Indeed to the casual observer the beach rock appears barren.

These observations suggest that the beach rock provides a rigorous habitat. High temperatures must be endured by the animals found there, since on sunny days when the tide ebbs the rocks become decidedly hot to the touch. Also since wave action at low tidal levels is negligible there is no splash and spray to keep the intertidal beach rock moist, and desiccating conditions prevail generally. In addition when strong winds are blowing, coral sand is blown over the beach rock.

During higher tidal levels a strong tidal current carrying abrasive particles courses along the rock.

It is not surprising therefore that the beach rock fauna is sparse and that sedentary forms are almost entirely absent.

(ii) *The Reef Crest.*—A traverse was made on the reef crest at a spot chosen to include numerous negro-heads in addition to the usual substratum of coral rubble.

Negro-heads

Two zones were evident (see Fig. 3(*b*)).

(1) *Oyster Zone.*—On the larger negro-heads, which extended up to H.W.N., a poorly developed zone of *Crassostrea amasa* was found. The lower limit was at approximately M.S.L., as it is typically on the mainland.

(2) *Barnacle Zone.*—From M.S.L. to just above L.W.N., which was the approximate upper level of the reef crest, a zone of barnacles occurred. *Tetraclita vitiata* was the dominant species but *T. coerulescens* was common and *Balanus imperator* was present.

Apart from chitons (*Acanthozostera gemmata* and *Onithochiton quercinus*) the only other common animals on the negro-heads were the limpet *Penepatella inquisitor*, the pulmonate *Siphonaria australis*, and the boring echinoid *Echinometra mathaei*.

Thus, as at mainland localities, oyster and barnacle zones were found between neap tide levels. However, the oysters were much less dense than on the mainland, and the barnacles belonged to species which occurred at few mainland localities.

Semi-consolidated coral rubble

This was partially cemented together by "lithothamnion",* and between the reef crest (slightly above L.W.N.) and the reef edge (at L.W.S.) the habitat was complicated by numerous drainage channels and pools, most of which supported a rich coral growth. Usually three zones could be recognized (Fig. 3(*b*)):

(1) *Algal Zone*.—On the rubble of the reef crest lithothamnion and unidentified small brown algae were abundant. The lower limit of this zone was generally about M.L.W., but this zone was truncated frequently by the next.

(2) *Zoanthid Zone*.—A carpet of zoanthids (chiefly *Palythoa* spp.) often occurred from just below L.W.N. to just below M.L.W. On the mainland, zoanthids were very restricted in their occurrence although they occurred at a comparable height.

(3) *Coral Zone*.—Living corals with an increasing proportion of bracket-shaped *Acropora* spp. predominated from about M.L.W. to the reef edge, which was undercut to some extent. Corals occur at equivalent levels at some mainland localities but there are fewer species, the commonest species are different, and their ecological significance is much less.

(*c*) *Comparison of Heron Island and Mainland Zonation Patterns*

In summary the zonation at Heron I. differed from that on the mainland in the following major respects:

(i) The littorinids *Nodilittorina pyramidalis* and *Melaraphe melanacme* were not as abundant as on the mainland and the respective zones occupied were lower.

(ii) An upper barnacle (*Chthamalus*) zone was not represented at Heron I.

(iii) The oyster zone (*Crassostrea amasa*) was not as well developed as on the mainland.

(iv) The lower barnacle zone was formed by a different species of *Tetraclita*.

(v) The algal zone of the mainland was replaced to a large extent by a lithothamnion-zoanthid-coral zone at Heron I.

VI. Faunistic Composition and Zonation on the Continental Islands

The continental islands visited can be divided arbitrarily into two groups as follows:

Those islands lying between lat. 20° and 22° S. where average wave action varies from slight to severe.

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* "lithothamnion" is used here to denote unidentified, encrusting, calcareous, algal species.

Those islands lying between lat. 17° and 22° S. where wave action is equivalent.

Analysis of zonation and species composition in the first case should give some indication of the effects of different degrees of wave action and in the second case should give some indication of the effects of latitude.

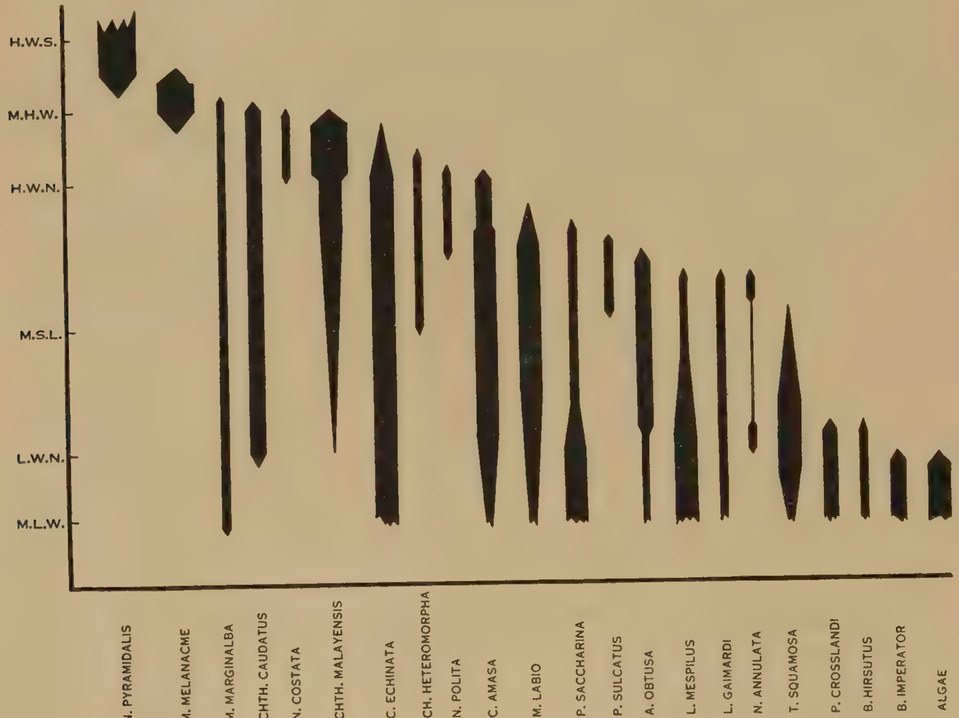

Fig. 4.—Zonation of organisms on rocky shores at Flat Top I. (diagrammatic); for key to densities see Fig. 3(*b*).

(*a*) *Effects of Wave Action*

Since the islands visited between lat. 20° and 22° S. lie at varying distances from the mainland, it is convenient to place them in the following categories: coastal sheltered, offshore sheltered, and offshore exposed.

(i) *Coastal Sheltered.*—The species composition and zonation at Flat Top I., which is about 3 miles from the mainland, are summarized in Figure 4. The picture obtained was typical of that found on the northern Queensland mainland (see Endean, Kenny, and Stephenson 1956). Thus upper and lower littorinid zones, an upper barnacle (*Chthamalus*) zone, an oyster zone, a lower barnacle (*Tetraclita*) zone, and an algal zone were represented. Other organisms found in these main zones are all common on the mainland.

(ii) *Offshore Sheltered.*—Figure 5 shows results obtained at Dent I., this and Pine I. being regarded as offshore sheltered localities. Although the same zones were present as on the mainland, the usual species of the lower barnacle zone (*Tetraclita squamosa*) had declined in importance. It was replaced to a large extent by *T. rosea*, which is abundant in southern Queensland but is only sparsely represented on the coastline north of Hervey Bay.

The lower littorinid (*Melaraphe*) zone was not well developed at Dent I. but was fully developed at Pine I., where the zonation otherwise resembled that at Dent I.

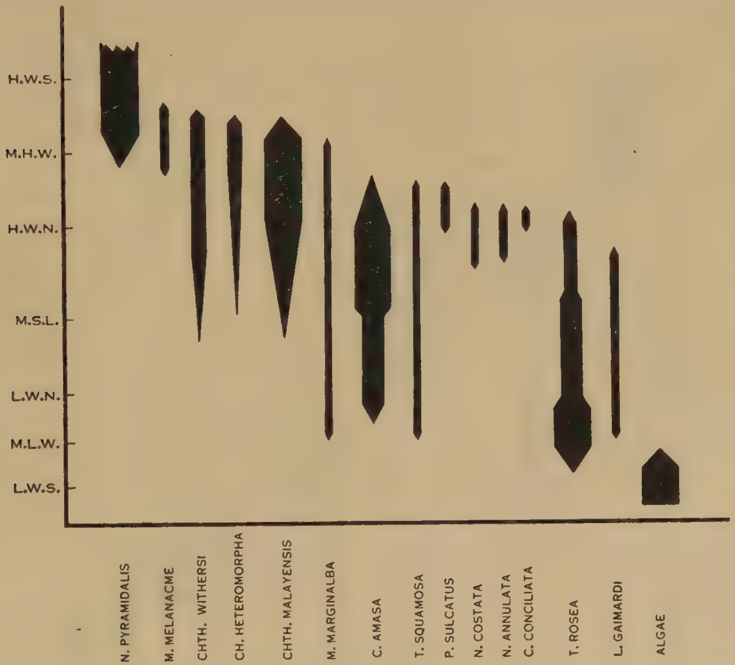

Fig. 5.—Zonation of organisms on rocky shores at Dent I. (diagrammatic); for key to densities see Fig. 3(*b*).

(iii) *Offshore Exposed.*—Bailey I., Coppersmith I., and High Peak I. are placed in this category. Results obtained at Bailey I. are summarized in Figure 6. Above M.S.L. the picture was similar to that found at the islands just discussed. However, below M.S.L. changes had occurred. *Tetraclita rosea* plastered the rocks from just below M.S.L. to just below L.W.N. Between this level and M.L.W. a zoanthid zone occurred and this was followed by a coral-lithothamnion zone.

At High Peak I. and Coppersmith I. zonation closely resembled that at Bailey I. with the following exceptions:

(1) At High Peak I. the *T. rosea* zone extended from L.W.N. to well above M.S.L.

(2) At Coppersmith I. corals and zoanthids were somewhat patchy.

Consideration of the above data indicates that:

(1) With increased wave action *Tetraclita rosea*, corals, zoanthids, and lithothamnion become increasingly important.

(2) Exposure to increased wave action results in a decline in the abundance of, and a raising of the level of the zone occupied by, *Tetraclita squamosa.*

(3) The greater the wave action the higher the junction between the *T. rosea* and the oyster zones.

(4) *Crassostrea echinata, Pomatoleios crosslandi,* and *Lunella mespilus* are essentially mainland species, being found at none of the offshore localities. It would appear that the degree of wave action, rather than the distance from the mainland, is the salient factor involved in bringing about the differences listed above. In this respect it should be noted that corals, zoanthids, and lithothamnion were not found at Pine I., which is the most distant from the mainland of all the continental islands visited but is protected by larger islands from excessive wave action.

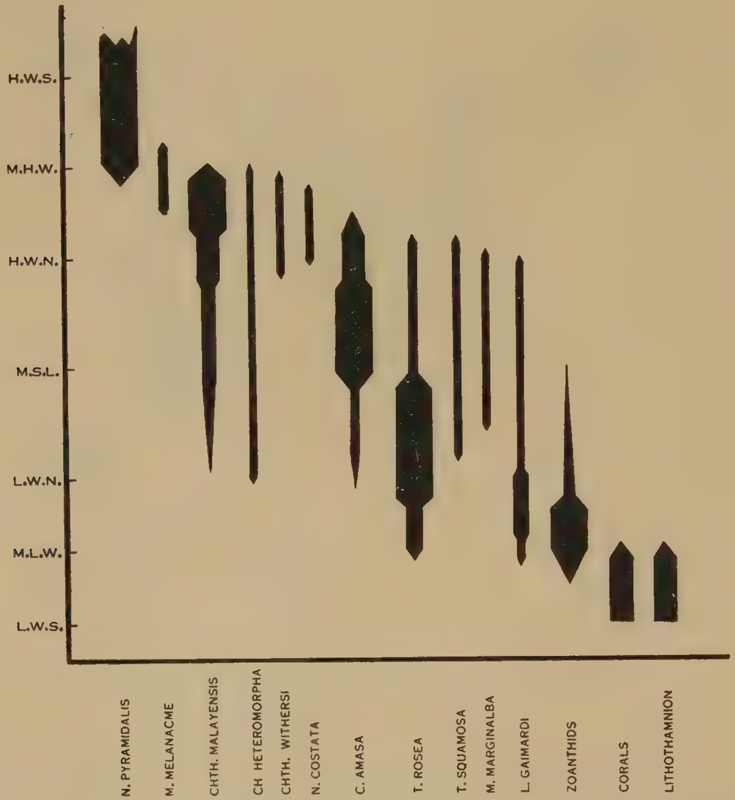

Fig. 6.—Zonation of organisms on rocky shores at Bailey I. (diagrammatic); for key to densities see Fig. 3(*b*).

(*b*) *Effects of Latitude*

It is considered that the average extent of wave action at island localities north of lat. 20° S. is approximately equivalent to that at the "offshore sheltered" localities south of 20° S. previously discussed.

(i) *Islands Lying between Latitudes* 20° *and* 22° *S.*—Zonation on Dent and Pine Is. has already been discussed. Features of interest are:

(1) The presence of a *Tetraclita rosea* zone.

(2) The decline in the importance of *T. squamosa.*

(3) The absence of corals, zoanthids, and lithothamnion.

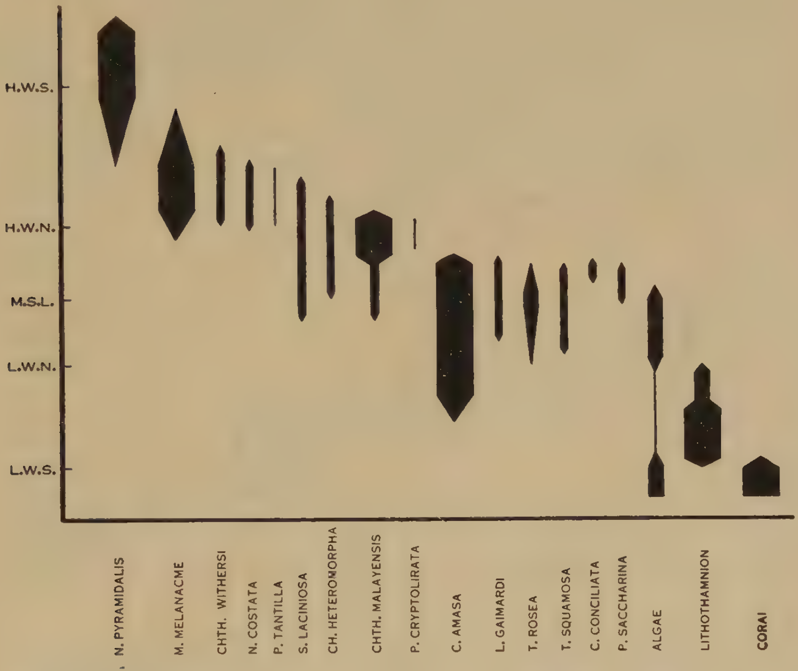

Fig. 7.—Zonation of organisms on rocky shores at Magnetic I. (diagrammatic); for key to densities see Fig. 3(*b*).

(ii) *Islands Lying between Latitudes* 19° *and* 20° *S.*—Magnetic I. is about 5 miles from the mainland. Zonation (Fig. 7) was similar to that found at typical northern Queensland mainland localities with the following exceptions:

(1) *Nerita costata* was a dominant.

(2) The zone dominated by the oyster extended from well above M.S.L. to below L.W.N. *Tetraclita squamosa* was very sparse and extended higher than usual.

(3) Below M.S.L. and extending to L.W.N. there was a zone in which *Tetraclita rosea* was common.

(4) Lithothamnion formed a zone below L.W.N.

(5) Below M.L.W. corals were common but somewhat patchy in their occurrence.

At nearby Bay Rock I. zonation was similar but corals were not observed.

(iii) *Islands Lying between Latitudes* 16° *and* 18° *S.*—Kent I. is about 4 miles from the mainland and about 10 miles from Etty Bay, a mainland locality visited previously. Zonation on the island (Fig. 8) was similar to that at Etty Bay, with the following exceptions:

(1) *Crassostrea amasa* dominated the entire region, extending from about half-way between H.W.N. and M.S.L. almost to L.W.N.

(2) *Tetraclita squamosa* was consequently less abundant, but extended much higher (up to H.W.N.) than usual.

(3) The chiton *Acanthozostera gemmata* was a subdominant.

(4) A few specimens of *Tetraclita vitiata*, which was not observed at Etty Bay, were found just above L.W.N.

(5) Lithothamnion was a dominant from L.W.N. to M.L.W.

(6) Below M.L.W. corals were dominant in exposed situations and zoanthids were abundant in channels and crevices.

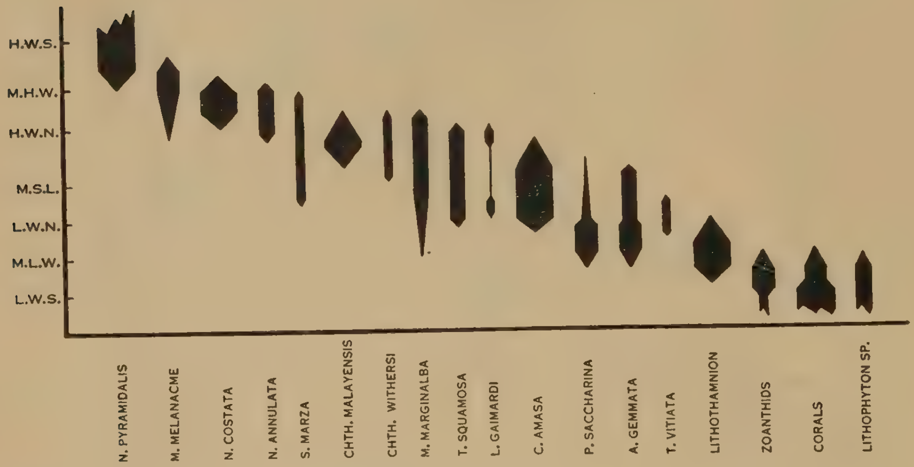

Fig. 8.—Zonation of organisms on rocky shores at Kent I. (diagrammatic); for key to densities see Fig. 3(*b*).

Fitzroy I. is about 50 miles to the north of Kent I. and about 5 miles from the mainland. Zonation on both was similar with respect to the great development of the oyster zone. However, at Fitzroy I. the *Chthamalus malayensis* zone was poorly developed, and in the region it normally occupies *Siphonaria laciniosa* was a dominant.

It was noted that on coral rock adjacent to the main traverse *Tetraclita vitiata* was very common near L.W.N.

Consideration of the above data shows that:

(1) The typical algal zone of the northern Queensland mainland, although well represented on the islands south of lat. 20° S. not subjected to excessive wave action, is replaced by corals, lithothamnion, and zoanthids on islands in lower latitudes.

(2) *Tetraclita rosea* is replaced by *T. vitiata* north of about lat. 19° S.

(3) *Crassostrea amasa* appears to become more abundant as lower latitudes are approached.

VII. Discussion

(a) *The Ecology and Distribution of Important Species*

The present study in conjunction with previous work (Endean, Kenny, and Stephenson 1956) throws new light on the ecology and distribution of several species as outlined below.

(i) *Littorinids.—Nodilittorina pyramidalis* is not especially common at Heron I., but is just as abundant on the continental islands as on the mainland. The species forming the lower littorinid zone on the mainland (*Melaraphe melanacme*) is again not very common at Heron I., while on the continental islands its abundance varies. At the more exposed islands it is usually sparse, and the zone it normally occupies is inhabited by *Chthamalus malayensis*. The present results support the previous suggestion that *M. melanacme* is adversely affected by severe wave action.

M. undulata occurs sporadically on the mainland, on the continental islands, and at Heron I., but is not often very common.

(ii) *Barnacles.—Tetraclita squamosa*, essentially a northern Queensland mainland species, is represented on all the continental islands visited but rarely attains dominance. Also, it is far less common on the weather than on the lee side of the more exposed islands, which indicates that it prefers somewhat sheltered waters. This may partially explain its absence from Heron I. and south of about lat. 25° S. on the Queensland coast.

On the continental islands south of lat. 20° S. the abundance of *T. squamosa* is related to the abundance of *T. rosea*. Also, when the two barnacles are found on the same traverse, *T. squamosa* is always higher (as high as H.W.N.) than the level at which it normally occurs on the mainland.

The sporadic occurrence of *T. rosea* north of lat. 25° S. on the mainland has already been detailed (Endean, Kenny, and Stephenson 1956). It was concluded that this southern zoning species preferred wave-lashed situations and that its reduced abundance north of 25° S. was related to increased shelter.

The present observations support this view. Thus at High Peak I., the most exposed of the continental islands visited, *T. rosea* plastered the rocks from well above M.S.L. to L.W.N. At Bailey I. and Coppersmith I., which are also exposed to oceanic swell, the barnacle was dominant from M.S.L. to L.W.N. At Dent I. (somewhat protected) it was a co-dominant with *Crassostrea amasa*. Only a few specimens were obtained from Magnetic I., which must be near the northern limit of this species.

Previously the occurrence of *T. rosea* at Cannonvale and Cape Edgecumbe was puzzling since the species had not been observed at localities between Cannonvale and Bargara (about 300 miles apart). Indeed until Cannonvale was visited it was thought that the species did not extend very far to the north of the biogeographical boundary at about 25° S.

The present work has revealed that the species has extended its range to the north of this boundary by way of the continental islands. The more northerly islands of the Cumberland Group are separated from the mainland only by the narrow Whitsunday Channel, and apparently the species has "overlapped" onto the mainland in this region.

T. vitiata and *T. coerulescens* seem to be typically Reef species, and are abundant on coral boulders lying on intertidal reefs. North of the Whitsunday Group the Great Barrier Reef approaches the mainland waters, and this may account for the presence of *T. vitiata* at Kent I. and Fitzroy I., and of both *T. vitiata* and *T. coerulescens* at Yorkey's Knob near Cairns. Their absence from the continental islands south of Kent I. may be due to their inability to compete with *T. rosea*. It is not a response to lower temperature or increased wave action, since these factors are tolerated at Heron I., which is further to the south than any of the continental islands visited.

Alternatively it may indicate that they prefer the coral environment. There is some evidence to suggest that *T. vitiata* prefers a substratum of dead coral. Thus at Kent I., isolated clumps of coral rock bore numerous specimens of *T. vitiata* whilst the species was much less common on adjacent granitic rocks.

As on the mainland, the abundance of *Chthamalus caudatus* and *Octomeris brunnea* on the continental islands seems to be determined by the availability of crevices and shaded overhangs. The distribution of *C. withersi* both on the mainland and continental islands is somewhat sporadic and its abundance is apparently inversely related to the abundance of *C. malayensis*. The latter barnacle was well represented in its usual zone on the continental islands, although absent from Heron I. Another factor of possible importance here is fluctuation in salinity. It was noted previously that *C. malayensis* is absent from localities where the salinity is liable to fluctuate periodically (e.g. Yeppoon, Point Vernon). On the other hand, *C. withersi* was present at these localities. *Balanus* sp. nov. I seems to flourish best in waters of reduced salinity, as noted previously, and the total absence of this species from the offshore islands supports this view. As on the mainland, the purple barnacle *B. imperator* has a rather sporadic distribution on the islands visited, and because of the frequent occurrence of this species attached to submarine objects washed up after storms it is suspected that it is essentially a sublittoral form.

(iii) *Chitons.—Liolophura gaimardi*, the common mainland chiton, is also common on the continental islands. It is replaced on the coral islands (Heron, Lady Elliott) by *Acanthozostera gemmata*, which has been recorded at certain localities on the mainland (Endean, Kenny, and Stephenson 1956) but appears to be primarily a Barrier Reef species.

Onithochiton quercinus (a common mainland and continental island species) occurs in small numbers on negro-heads on the coral islands. As noted previously, it seems always to be closely associated with coralline algae.

(iv) *Limpets.—Patelloida saccharina stella*, *Cellana conciliata*, and *Chiazacmea heteromorpha* are common both on the Queensland mainland and on the continental islands. These limpets were not found on the coral islands studied. The only limpet noted at Heron I. was *Penepatella inquisitor* (also recorded from North-West Islet in the Capricorn Group), which occurred only on the lower parts of negro-heads near the reef crest on the south side of the reef.

(v) *Pulmonates.—Siphonaria atra*, *S. marza*, and *S. laciniosa*, all of which are represented on the Queensland coast, were also found on the continental islands. The absence of *S. rucuana* from these islands is noteworthy since on the mainland coast this species is frequently found associated with and sometimes replacing *S. laciniosa.* Although none of these species of *Siphonaria* was recorded from Heron I., an additional species, *S. australis*, was found there. This species appears to be confined to the Capricorn Group.

Hubendick (1955) has suggested that *S. marza*, *S. atra*, and other "species" (represented in Queensland) comprise an "Indian West-Pacific form group" of variable and transitional siphonarias, and if this is so, *S. marza* and *S. atra* are variants of the same species. However, although superficially similar, *S. australis* is retained as a distinct species by Hubendick.

(vi) *Thaids.*—The common mainland thaid, *Thais distinguenda*, was poorly represented on the continental islands and this seems to be related to the sparseness of its usual prey, *Tetraclita squamosa*. The absence of both species from Heron I. is significant in this respect.

(vii) *Other Gastropods.—Nerita costata* and *N. annulata* appear to be mainland species. *N. costata* is found on exposed rock faces and was present on all the exposed continental islands visited. *N. annulata*, however, seems to prefer more sheltered situations and is usually found amongst rubble and boulders. It was not found on the more exposed islands. The mainland form of *Planaxis sulcatus* has similar habitat requirements and was found at the same localities as *N. annulata*. On the other hand, the speckled form of *P. sulcatus* seems to be confined to Barrier Reef waters although it too is found in sheltered conditions.

Nerita polita was just as common at Heron I. as it was at mainland localities. This species, however, is frequently more plentiful under rubble and boulders than upon them.

(viii) *Bivalves.—Crassostrea amasa* on the Queensland mainland forms a zone usually between H.W.N. and M.S.L. Its lower level abuts on the upper level of the *Tetraclita squamosa* zone, and the junction between these two zones occurs at a relatively constant height. On the exposed continental islands the oyster forms a zone at a similar height to that on the mainland, but on the more sheltered continental islands it extends frequently as low as L.W.N. To a large extent the lower level of the oyster zone on the continental islands south of lat. 20° S. is determined by the degree of development of the *Tetraclita rosea* zone. With increasing wave action the upper limit of this zone is raised and the width of the oyster zone correspondingly reduced. On the continental islands visited to the north of about lat. 20° S. neither *T. squamosa* or *T. rosea* are dominants and the oyster extends further down the beach than usual.

A general impression was gained that on the continental islands the abundance of the oyster increases with decreasing latitude. Reference to traverses made on the mainland reveals that the oyster was most abundant at Whitecliffs, the most northerly locality visited. In order to ascertain whether this is a distinct trend, visits to localities still farther north are required.

Crassostrea echinata seems to be a mainland species, and the total absence of this species from all of the continental islands but the near-mainland Flat Top I. lends support to the contention advanced previously (Endean, Kenny, and Stephenson 1956) that this species is adapted to waters of reduced salinity.

Brachyodontes hirsutus was found on none of the islands visited except Flat Top I. Its frequent occurrence in semi-estuarine situations on the mainland indicated that it preferred waters of reduced salinity and this may be the major factor involved here.

(ix) *Serpulids.—Pomatoleios crosslandi* was absent from all the islands visited except Flat Top I. This supports the view, previously advanced, that this species prefers sheltered waters. It would appear also that it is capable of tolerating a fluctuating salinity.

(x) *Zoanthids.*—On the mainland, zoanthids were common only at a few localities. On the continental islands most exposed to wave action, zoanthids (chiefly *Palythoa* sp.) formed a zone between L.W.N. and M.L.W. At Heron I. they were particularly dense near the reef crest. Apparently they prefer localities with considerable wave action.

At Fitzroy and Kent Is. zoanthids were common. It is suspected that this is due to the proximity of the reefs of the Great Barrier Reef.

(xi) *Corals.*—These are essentially sublittoral species, and the complexities of their systematics and distribution are such as to deserve separate treatment. For a comparison of the coral faunas of Low Isles and Heron I., together with a general discussion of some of the problems of biogeography, the reader is referred to Stephenson and Wells (1956).

However, the present work has shown that corals colonizing intertidal rock faces are common on the more exposed of the continental islands visited south of lat. 20° S. and absent from the more sheltered ones. North of lat. 20° S. coral was found at all island localities visited.

(xii) *Algae.*—On those islands where wave action was slight an algal zone was represented below L.W.N. and this zone appeared to have a similar specific composition to that of its mainland counterpart. Where wave action was well marked, most algae with the exception of lithothamnion declined in importance.

Lithothamnion was found at all localities where wave action was severe. In fact the extent of the development of the lithothamnion zone at any locality was directly related to the degree of wave action. Thus at High Peak I., Bailey I., and Coppersmith I. lithothamnion zones were prominent. A band of lithothamnion was prominent on the reef crest at Heron I. There is a considerable literature on lithothamnion on coral structures (see Wells 1954), and study of this supports the general conclusion that the importance of lithothamnion increases with increased wave action.

(*b*) *Barrier Reef Species, Mainland Species, and Continental Island Species*

In order to investigate a possible west-east transition in the Queensland littoral fauna as coastal waters merge into Great Barrier Reef waters it would be desirable to visit a series of islands forming a west-east chain from the mainland to the Barrier Reef. Such chains do not exist, since the principal axes of the island groups found off the coast are to the north-north-west, paralleling the geological "grain" of the coastal region.

Another approach is to estimate the ratio of Barrier Reef to mainland species at each of a number of islands and to correlate this with their geographical positions. However, it is difficult to ascertain which species are typically Barrier Reef species and which typically mainland.

If relative abundance be taken as a criterion, then the intertidal species investigated at Heron I. can be categorized as follows:

Mainland species.—*Nodilittorina pyramidalis*, *Melaraphe melanacme*, *M. undulata*, and *Crassostrea amasa*.

Heron I. species.—Most species of corals, zoanthids (particularly *Palythoa* sp.), *Tetraclita vitiata*, *T. coerulescens*, *Acanthozostera gemmata*, the speckled form of *Planaxis sulcatus*, and *Penepatella inquisitor*.

Species equally common to the mainland and Heron I.—*Balanus imperator*, *Nerita polita*, and *N. albicilla*.

Although zonation and faunistic assemblages at Heron I. are considered typical of those occurring in the Capricorn and Bunker Groups they may not be typical of those occurring at comparable situations farther north. Because of transport difficulties, it has not been possible as yet to visit other cays, intertidal reefs, or the reefs of the outer Barrier. However, data from Low Isles (lat. 16° 23′ S.) are available.

Stephenson *et al.* (1931) in discussing organisms found on beach rock and coral boulders at Low Isles noted that *Crassostrea amasa* (as *Ostrea mordax*) was "extremely abundant". Other common organisms found were *Planaxis sulcatus*, *Chama jukesi*, *Acanthozostera gemmata*, *Grapsus strigosus*, *Clibanarius virescens*, a vermetid mollusc, and a zoanthid (*Palythoa* sp.).

Additional species recorded more recently from the beach rock at Low Isles include *Nodilittorina pyramidalis*, *Melaraphe melanacme*, *M. undulata*, *M. coccinea*, *Siphonaria atra*, *Patelloida saccharina stella*, *Perna nucleus*, *Monodonta labio*, *Spondylus ducalis*, *Tetraclita coerulescens*, *T. vitiata*, *Nerita polita*, and *N. albicilla* (Stephenson, Endean, and Bennett, unpublished data).

Fewer species, therefore, occurred on the beach rock and boulders at Heron I. than at Low Isles. This may be partially due to attenuation of the fauna with increasing latitude. Thus *Melaraphe coccinea* has not been noted south of Cairns on the Queensland coast. Although *Chama jukesi*, *Spondylus ducalis*, and *Tetraclita coerulescens* are present at Heron I., they are much less common there than farther north.

The occurrence of the common mainland species *Patelloida saccharina stella*, *Monodonta labio*, *Grapsus strigosus*, *Siphonaria atra*, and *Perna nucleus* at Low Isles but not at Heron I. may be due to the fact that Low Isles is only about 7 miles from the mainland whilst Heron I. is about 45 miles distant.

On the available evidence based on Low Isles as well as Heron I. it would appear therefore that the following can be regarded as Barrier Reef species: *Tetraclita vitiata*, *T. coerulescens*, *Chama jukesi*, *Spondylus ducalis*, *Acanthozostera gemmata*, the speckled form of *Planaxis sulcatus*, zoanthids, and most species of corals.

The following can be regarded as the more important of the typically mainland species: *Nodilittorina pyramidalis*, *Melaraphe melanacme*, *Chthamalus malayensis*, *C. withersi*, *C. caudatus*, *Octomeris brunnea*, *Tetraclita squamosa*, *Balanus* sp. nov. I, *Crassostrea amasa*, *Pomatoleios crosslandi*, *Lunella mespilus*, *Thais distinguenda*, *Nerita costata*, *N. annulata*, *Patelloida saccharina stella*, and *Chiazacmea heteromorpha*.

It is apparent from the data already given that the intertidal faunas of all the continental islands investigated are much more closely related to that of the mainland than to that of the Barrier Reef, despite the occurrence on some islands of such Barrier Reef species as *Tetraclita vitiata*, *Acanthozostera gemmata*, zoanthids, and corals. It is probable, therefore, that the mainland intertidal fauna does not merge gradually with the Barrier Reef intertidal fauna. On the contrary, it would seem that the Barrier Reef and mainland intertidal faunas are distinct entities. Some overlapping of the two faunas does occur. Thus at Low Isles some typically mainland species occur and on the continental islands some Barrier Reef species occur. The position on the continental islands, however, is complicated to some extent by three chief factors:

(1) The geographical position of the continental island determines the amount of wave action, and usually the further south the island, the greater the wave action. High Peak, Bailey, and Coppersmith Is. are affected by oceanic swell entering via the Capricorn Channel. It is noteworthy that corals and zoanthids are well represented on these islands. Distance from the mainland does not seem to be a factor of major importance affecting these organisms in this case, but their abundance does seem to be linked to increased wave action (see Section VI(*a*)).

(2) Because the Great Barrier Reef diverges seaward from Cape Grafton southwards, Fitzroy and Kent Is., although only 3 to 4 miles offshore, are actually one-third as far from the Barrier Reef as Bailey I. (about 20 miles offshore), or Pine I. (about 35 miles offshore). It is of interest, therefore, that of islands with roughly equivalent wave action the more northerly ones possess the higher proportion of Barrier Reef species. This suggests that proximity to the Barrier Reef may be a factor of importance in determining the specific composition, although temperature variation with latitude is of course another factor which cannot be ignored.

(3) The number of browsing forms represented at a particular island seems to be influenced by shore profile. Usually the greater the amount of rubble and the gentler the slope of the shore, the greater the number of browsing animals (e.g. *Planaxis sulcatus*, *Monodonta labio*, and *Nerita* spp.). The majority of the continental islands visited presented precipitous or steeply sloping rock surfaces to the water. To some extent this may account for the facts that the continental island fauna was less diverse than the mainland fauna, and that dominant animals were more abundant in their respective zones than at mainland localities.

Essentially the fauna of the continental islands is similar to that of the mainland. However, a few mainland species are not represented, and there is an occasional intrusion of some species found commonly on the beach rock and the reef crest of coral structures. Individual differences between the faunas of the islands are due mainly to differences in shore profile, wave action, and latitude.

Hedley (1904), presumably using data based chiefly on his molluscan studies, placed the Queensland marine fauna in the area extending from Torres Strait to Moreton Bay into a single Solanderian Province. Subsequently (1926) he placed the southern limit of this province at Wide Bay (about 26° S.). Clark (1946), after a study of Australian echinoderms, agreed with Hedley's delineation of the Solanderian Province. Endean, Kenny, and Stephenson (1956), after a study of intertidal zonation on the Queensland mainland, placed the southern limit of the Solanderian Province at about lat. 25° S.

Whitley (1932), after extensive studies of Queensland fish, restricted the term "Solanderian" to the Great Barrier Reef fauna and gave the name "Banksian" to the fauna of the Queensland coast proper. Study of the present data reveals that such a longitudinal division of the Queensland marine fauna north of lat. 25° S. may indeed be warranted if the continental island fauna is associated with the mainland fauna. However, further work, particularly in the northern part of Queensland, is required before the line separating Solanderian and Banksian Provinces can be drawn with any confidence.

The question arises why the faunistic composition and zonation of intertidal organisms found on the coral islands should differ markedly from that of the continental islands and the mainland north of lat. 25° S. Although the problem is a complicated one and any attempts to answer it premature, an analysis of the results of this and the previous paper (Endean, Kenny, and Stephenson 1956) does throw some light on the matter.

Factors found to play a definite role are:

(i) *Wave Action.*—In general, wave action is more pronounced within Barrier Reef waters than on the mainland. Particularly is this so in the southern parts of the Barrier Reef, where the reefs do not form such a continuous chain as they do further north.

The extent of wave action on the continental islands varies, and it is significant that the more exposed of the continental islands possess a lithothamnion-zoanthid-coral zone as does the reef crest at Heron I. Indeed lithothamnion, zoanthids, and most coral species seem to exhibit a preference for a greater degree of wave action than that normally found on the northern Queensland mainland.

Of the common northern Queensland mainland species the ones that appear to be adversely affected by strong wave action are *Melaraphe melanacme* and *Tetraclita squamosa*. These species are commoner on the lee shores of the continental islands than on the windward shores, and commoner on the mainland than on the more exposed of the continental islands.

(ii) *Salinity, Turbidity, and Rainfall.*—It was noted previously (Endean, Kenny, and Stephenson 1956) that because of the large outflow from many Queensland rivers during the summer months, coupled with the damming effect of the Great Barrier Reef, the salinity of the water at mainland localities north of lat. 25° S. must fluctuate periodically. Unfortunately, because of lack of salinity data, the range of these fluctuations is not known, nor is the average distance from the mainland at which they become negligible. Because of its relatively great distance from the mainland (45 miles) and the apparent clarity of the water it is very doubtful whether the salinity at Heron I. would be affected, but some of the coral islands further north are much nearer the mainland. Thus at Low Isles, which is about 7 miles from the mainland, Orr (1933) found that the salinity of the water was lowered significantly during the summer months. Presumably the salinity of the waters near the continental islands would be related to their distance from the mainland and to their proximity to the mouths of the longer rivers.

It is difficult to divorce the salinity factor from the turbidity factor. Mainland waters are undoubtedly characterized by a high degree of turbidity. On the other hand Barrier Reef waters, particularly those near the southern end of the Barrier Reef, are noteworthy because of their clarity.

Because of their absence from the coral islands and the majority of the continental islands and their frequent occurrence in semi-estuarine situations, the mainland species *Crassostrea echinata*, *Pomatoleios crosslandi*, *Balanus* sp. nov. I, and *Lunella mespilus* must be adapted to waters of reduced salinity. This is in accord with evidence presented previously (Endean, Kenny, and Stephenson 1956).

During cyclonic disturbances very heavy rainfall is usually experienced, and such cyclonic rains seem to play a major part in preventing corals from establishing themselves permanently at mainland localities.

(iii) *Substratum.*—A factor militating against colonization of the coral islands by *Crassostrea amasa* is the fact that there are relatively few structures to which it might become attached at its preferred level (H.W.N.–M.S.L.). The chief habitat of the oyster in reef waters is provided by negro-heads. These erratics only occur south of Cooktown (lat. 15° 28′ S.), in the cyclone belt, as was pointed out by Mayer (1918).

Even the negro-heads provide only a temporary foothold since they wear away relatively quickly. Hedley (1906, p. 458) observed that "all the aged rock oysters projected like spurs from the surface" (of the negro-heads) "to which they were attached by the ventral margin. Originally they were fixed by the umbonal end, and as the first point of attachment wore away they clung by the newer part of the valve".

Negro-heads and beach rock are the favoured habitats of *Acanthozostera gemmata*. The chitons make shallow excavations in these materials to which they retire during the day. Apparently they are unable to make similar excavations in the hard continental rocks, because on the continental islands and at the few mainland localities where they occur they occupy natural crevices in the rocks.

There is evidence that *Tetraclita vitiata* shows a preference for coral structures, as noted earlier. Substratum preference is also a factor which must be considered in any attempt to account for the absence of *T. rosea* from Heron I. This barnacle prefers wave-lashed situations and in southern Queensland is abundant in fully saline waters. It extends its range much further to the north than the latitude of Heron I., where conditions of wave action and salinity should suit its requirements.

Factors which warrant further consideration but have not as yet proved to play definite roles are:

(iv) *Temperature.*—The available data on water temperatures in Queensland coastal waters indicate that mean annual temperature varies uniformly with latitude. There do not appear to be any intrusions of markedly colder or warmer bodies of water either in the Barrier Reef region or in the channel between the Barrier Reef and the mainland.

Undoubtedly there is attenuation of both mainland and Barrier Reef species (see also Wells 1955) with latitude, and presumably temperature is the chief factor involved here. However, temperature itself does not appear to be a factor of importance in causing differences between the intertidal faunas of the coral islands on one hand and those of the continental islands and the mainland on the other.

(v) *Currents.*—Water currents off the east Queensland coast were discussed previously (Endean, Kenny, and Stephenson 1956). The position within reef waters, however, is complicated by the existence of strong tidal currents. These were also observed in the vicinity of some of the continental islands.

There is evidence that water movements affect the attachment of the larvae of certain species of barnacles (Walton Smith 1946) and an investigation of the effect of currents on the attachment of the larvae of Queensland barnacles would therefore be of value.

(vi) *The Coral Environment.*—The effect that huge masses of coral living in the immediate vicinity of mainland rocky shore animals would have on the general physiology and life histories of these animals is a matter which requires elucidation.

All the above factors, plus others not considered, may be involved in bringing about differences between the faunistic compositions and zonation patterns of intertidal animals found in Barrier Reef waters and those found on the mainland and continental islands. However, the unravelling of the respective roles of these factors must await the outcome of future research.

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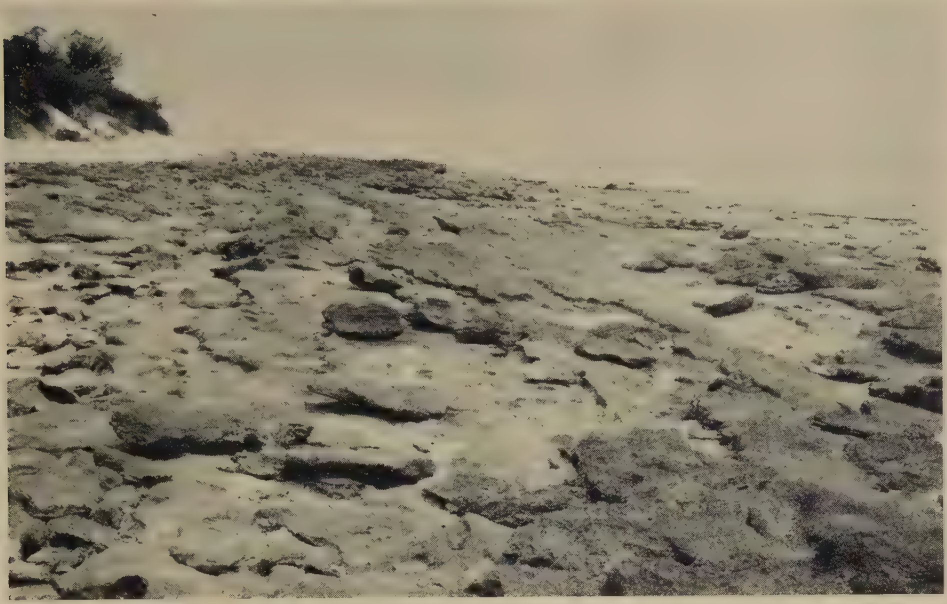

Fig. 1.—General view of beach rock at Heron I. (low tide).

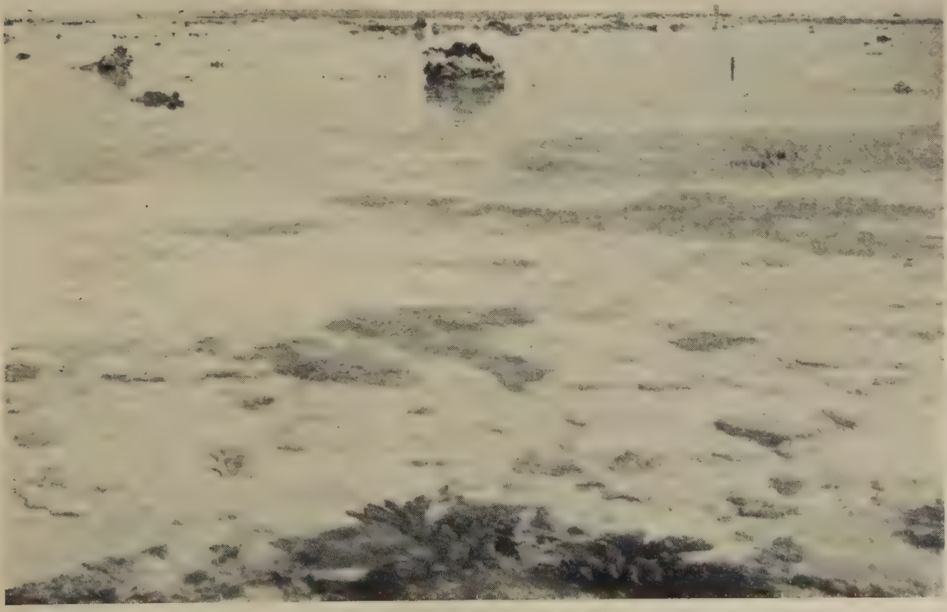

Fig. 2.—View across reef at Heron I., looking towards reef crest and showing negro-heads in background (low tide).

INTERTIDAL ORGANISMS ON QUEENSLAND ISLANDS

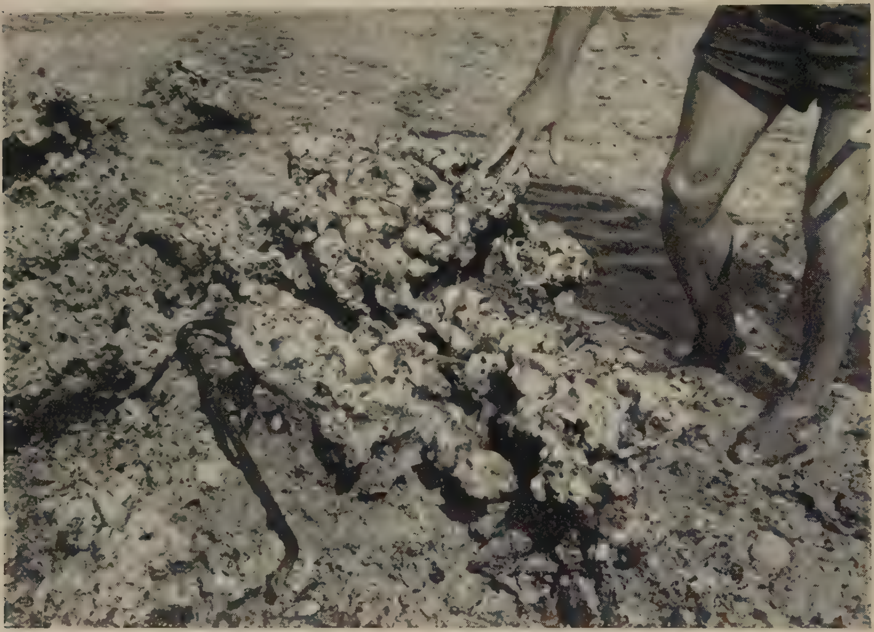

Fig. 1.—*Crassostrea amasa* on negro-head at Heron I.

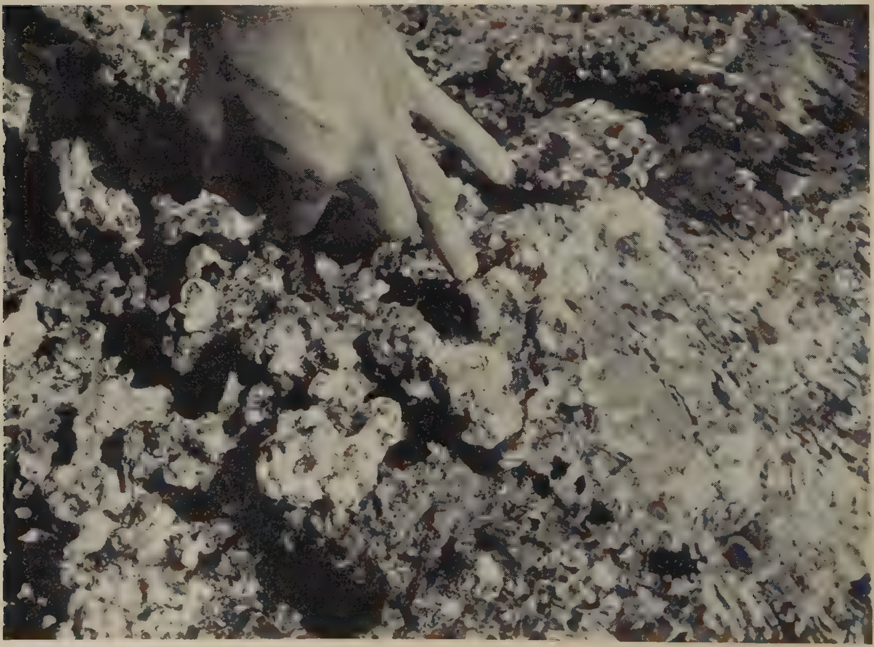

Fig. 2.—*Tetraclita vitiata* on negro-head at Heron I.

INTERTIDAL ORGANISMS ON QUEENSLAND ISLANDS

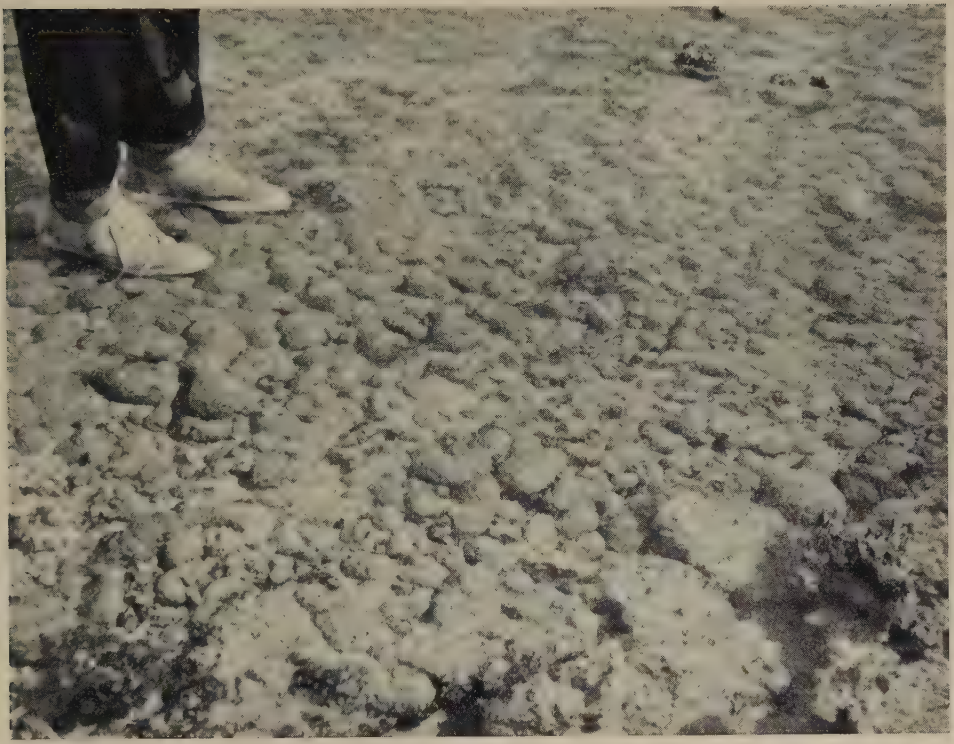

Fig. 1. -Zoanthid mat on reef crest at Heron I.

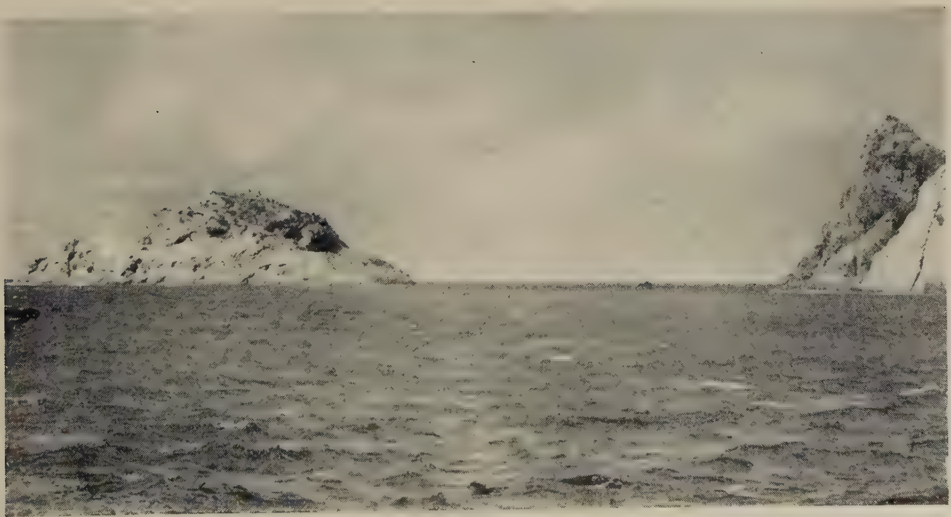

Fig. 2.- View of High Peak I.

INTERTIDAL ORGANISMS ON QUEENSLAND ISLANDS

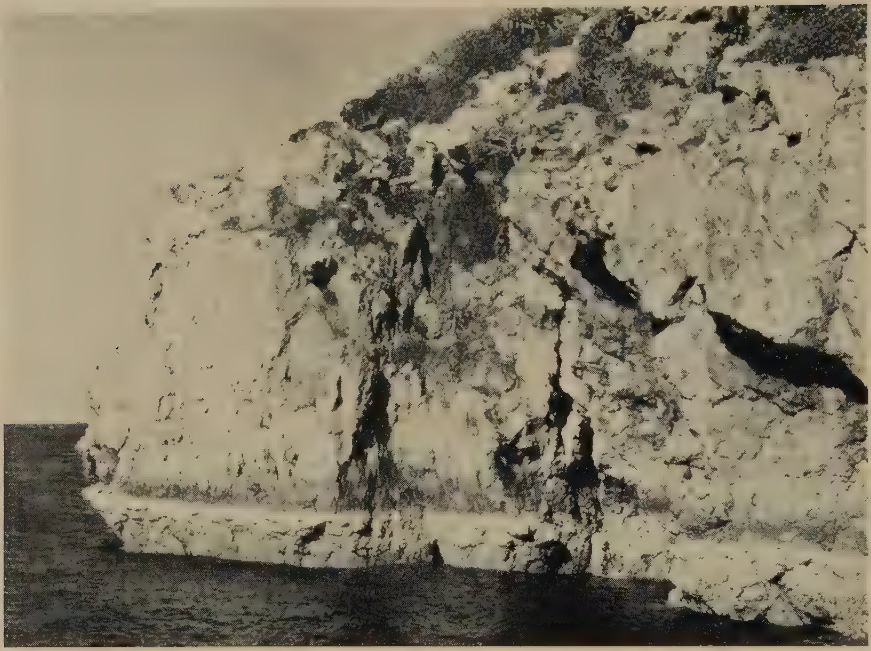

Fig. 1.—Vertical rock face at Bailey I. showing *Crassostrea amasa* and *Tetraclita rosea* zones.

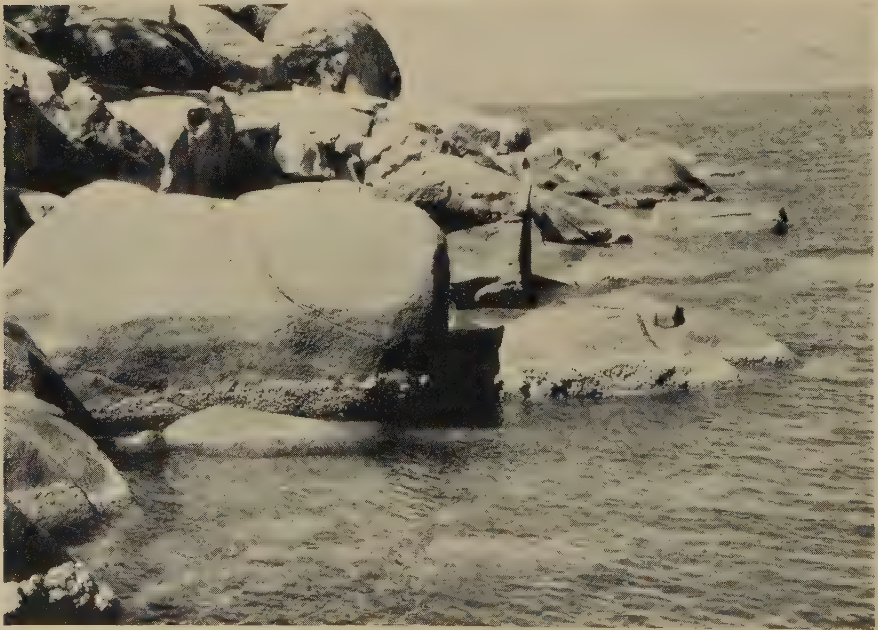

Fig. 2.—Granite boulders at Magnetic I. showing upper limit of *Crassostrèa amasa.*

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Appendix I

Notes on the Continental Islands Investigated

(1) *High Peak Island.*—Lat. 21° 57′ S., long. 150° 43′ E. Rock not sampled. Traverse facing W.; bare rock stepped back from H.W.S.; below H.W.S. vertical rock face plunging sheer into 10 fm of water; exposed; some oceanic swell; water clear.

(2) *Pine Islet.*—Lat. 21° 39′ S., long. 150° 14′ E. Rhyolite.
Facing WSW.; bare rock with narrow platform at L.W.N.; above platform, rock rises steeply with slight ledging; overall slope about 70°; below L.W.N. rock slopes at about 30° to L.W.S. and then plunges into deep water; semi-exposed; water turbid.

(3) *Flat Top Island.*—Lat. 21° 10′ S., long. 149° 15′ E. Rhyolite.
Facing SW.; succession of vertical faces with intervening gullies from L.W.S. to H.W.S.; overall slope about 20°; boulders and rubble in gullies; sheltered; wave action negligible; water very turbid.

(4) *Bailey Island.*—Lat. 21° 1′ S., long. 149° 39′ E. Siliceous limestone.
Facing SW.; smooth rock from H.W.S. to L.W.S.; overall slope about 80°; rocks undercut at L.W.S. and overhang 3 fm of water; exposed; some oceanic swell; water slightly turbid.

(5) *Coppersmith Island.*—Lat. 20° 35′ S., long. 149° 8′ E. Granite.
Facing SW.; smooth rock face plunging into about 3 fm of water; overall slope about 80°; exposed; slight oceanic swell; water slightly turbid.

(6) *Dent Island.*—Lat. 20° 21′ S., long. 148° 56′ E. Rock not sampled.
Facing SW.; smooth rock face; overall slope about 30°; semi-sheltered; wave action slight; water slightly turbid.

(7) *Bay Rock Island.*—Lat. 19° 7′ S., long. 146° 45′ E. Granite and rhyolite.
Facing E.; bare ledged rock; deep gullies at right angles to shore; overall slope about 60°; exposed; water turbid.

(8) *Magnetic Island.*—Lat. 19° 9′ S., long. 146° 52′ E. Granite.
Facing S.; very large piled boulders with rounded contour; overall slope about 30°; exposed; water turbid.

(9) *Kent Island.*—Lat. 17° 41′ S., long. 146° 11′ E. Micaceous schist. Facing N.; bare rocky outcrops with near-vertical sides and gullies running between them at right angles to shore; sheltered; wave action slight; water turbid owing to local disintegration of rock.

(10) *Fitzroy Island.*—Lat. 16° 56′ S., long. 146° 0′ E. Granite. Facing NW.; smooth rounded boulders; overall slope about 20°; sheltered; water turbid.

Appendix II

List of Species

Annelida

POLYCHAETA

- *Pomatoleios crosslandi* Pixell

Mollusca

LORICATA

- *Acanthozostera gemmata* (Blainville)
- *Liolophura gaimardi* (Blainville)
- *Onithochiton quercinus* (Gould)

GASTROPODA

- Trochidae
  - *Austrocochlea constricta obtusa* (Dillwyn)
  - *Monodonta labio* (L.)
- Turbinidae
  - *Lunella mespilus* Gmelin
- Neritidae
  - *Nerita albicilla* L.
  - *Nerita annulata* Reeve
  - *Nerita costata* Chemnitz
  - *Nerita polita* L.
- Patellidae
  - *Cellana conciliata* Iredale
- Patelloididae
  - *Chiazacmea heteromorpha* Oliver
  - *Patelloida cryptolirata* Macpherson
  - *Patelloida saccharina stella* (Lesson)
  - *Penepatella inquisitor* Iredale
- Littorinidae
  - *Melaraphe coccinea* (Martyn)
  - *Melaraphe melanacme* (Smith)
  - *Melaraphe undulata* (Gray)
  - *Nodilittorina pyramidalis* Quoy & Gaimard
  - *Peasiella tantilla* (Gould)
- Planaxidae
  - *Planaxis sulcatus* (Born)
- Thaiidae
  - *Morula marginalba* (Blainville)
  - *Thais distinguenda* Dunker
- Siphonariidae
  - *Siphonaria atra* Pilsbry
  - *Siphonaria australis* Quoy & Gaimard
  - *Siphonaria laciniosa* (L.)
  - *Siphonaria marza* Iredale
  - *Siphonaria rucuana* Pilsbry

PELECYPODA

- Ostraeidae
  - *Crassostrea amasa* (Iredale)
  - *Crassostrea echinata* (Quoy & Gaimard)
- Mytilidae
  - *Brachyodontes hirsutus* (Lamarck)
- Chamidae
  - *Chama jukesi* Reeve
- Isognomontidae
  - *Perna nucleus* Lamarck
- Spondylidae
  - *Spondylus ducalis* Bolten

Arthropoda

CIRRIPEDIA

- Chthamalidae
  - *Chthamalus caudatus* Pilsbry
  - *Chthamalus malayensis* Pilsbry
  - *Chthamalus withersi* Pilsbry
  - *Octomeris brunnea* Darwin
- Balanidae
  - *Balanus imperator* Darwin
  - *Balanus* sp. nov. I Pope in MS.
  - *Tetraclita coerulescens* (Spengler)
  - *Tetraclita rosea* (Krauss)
  - *Tetraclita squamosa* (Bruguière)
  - *Tetraclita vitiata* Darwin

DECAPODA

- Grapsidae
  - *Grapsus strigosus* (Herbst)
- Paguridae
  - *Clibanarius virescens* Krauss

Echinodermata

ECHINOIDEA

- *Echinometra mathaei* (Blainville)

A CRITICAL SURVEY OF THE MARINE ALGAE OF SOUTHERN AUSTRALIA

I. CHLOROPHYTA

By H. B. S. Womersley*

[*Manuscript received January* 16, 1956]

Summary

This paper is a survey of all the known marine Chlorophyta of southern Australia, from the south-west corner of Western Australia to about the Victoria–New South Wales border, and including Tasmania. Full references to each species are given, all established synonomy, the type locality of each species and where the type specimen is deposited, and a summary of the known distribution. Critical notes on many species are given also.

Introduction

The need for a critical survey of the marine algae of southern Australia has been obvious for many years. The lists of Lucas (1912, 1913) of the marine algae of Australia were little more than an extraction from De Toni's "Sylloge Algarum" (De Toni 1889), without references, and with distribution records summarized so much as to be of little value. Lucas's (1928) list of Tasmanian algae has the same limitations, while his (1936) account of the marine algae of South Australia gives no references and is now very incomplete. May (1938 and later papers) has given a better account of many of the New South Wales species, but a complete survey of the known species of both the eastern and western coasts of Australia, as well as the north, is needed. In many cases it is still necessary to refer to Harvey's "Phycologia Australica" (1858–1863) for a reasonable account of any species.

Some years ago the writer compiled a card index of all names that have been applied to southern Australian algae, with all references and distribution records. During 1952 it was possible to visit herbaria in Britain, Europe, and the United States which house the type specimens of southern Australian marine algae. The vast majority of the types were studied, and specimens from the writer's collections were compared with them. In most cases it was possible to designate homeotypes, which are now housed in the Herbarium of the University of Adelaide. In some cases type fragments were made available, and photographs of all the macroscopic types were taken or are being obtained for the Adelaide University Herbarium.

The location of the type of each species is given in the following account, using the standard abbreviations of Lanjouw and Stafleu (1952). These abbreviations are given below. Notes on the location of the type specimens of the various collectors and authors are also given below.

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This paper, and accounts of the brown and red algae of southern Australia which will follow later, are based on the above information. While it is probably too much to hope that the references and synonomy are complete, it is hoped that future changes and additions will be minor ones. This and the succeeding accounts should enable future systematic and ecological studies to be based on a firm foundation, and limitations to algal studies in southern Australia should be largely removed.

This list is regarded as a preliminary to taxonomic revisions of genera and groups and to a future algal flora of the region.

In compiling this list, references have been checked if there were cause for doubt and much synonomy has been clarified. References to species in strictly ecological papers have been omitted. Unfortunately it has not been possible to check all locality records or specimens in all Australian herbaria (those in AD, MEL, and HO have been examined), so distribution ranges may have to be extended slightly in future. Very few specimens were designated as types by early authors, but where the original description is based on a single specimen this is regarded as the type. The type number is given when available, but as most collections are not numbered, the type specimen has been marked as such if this had not already been done. Where the original description is based on a number of specimens, or where there is doubt as to the original, a lectotype has been designated.

Unfortunately, an inadequate and misleading list of Tasmanian marine algae has been published recently (Guiler 1952). This is no more than a repetition of that of Lucas (1928) with some additions of species and localities (many of which are doubtful), and shows Guiler's lack of familiarity with his subject. No references are given and clearly there has been no attempt to check on literature or herbarium records. The green algae in the Herbarium of the Botany Department, University of Tasmania, have been checked by the writer, and some of Guiler's errors are corrected in this paper; little reliance can be placed on many other records. This type of paper, with its many spelling errors of specific names and of authors, will, it is hoped, be the last of such lists of Australian algae to be published.

The region included in this survey, from the south-west corner of Western Australia to about the Victoria–New South Wales border, and including Tasmania, is a distinct floristic region. Many species occur throughout it, and the algal flora is quite different from that of the warmer western and eastern Australian coasts. A few warmer-water species which do extend into southern Australia on the western or eastern coasts are included.

STANDARD ABBREVIATIONS OF HERBARIA (LANJOUW AND STAFLEU 1952)

AD	Department of Botany, University of Adelaide, South Australia.
B	Botanisches Museum, Berlin—Dahlem, Germany.
BM	British Museum (Natural History), London, England.
C	Botanical Museum and Herbarium, Copenhagen, Denmark.
CANB	Division of Plant Industry, C.S.I.R.O., Canberra, Australia.
CN	Institut Botanique, Caen, France.
E	Royal Botanic Garden, Edinburgh, Scotland.
ER	Botanisches Institut und Herbarium der Universität, Erlangen, Germany.
FI	Herbarium Universitatis Florentinae, Firenze, Italy.

HO	Department of Botany, University of Tasmania, Hobart, Tasmania.
K	Herbarium, Royal Botanic Gardens, Kew, London, England.
KIEL	Botanisches Institut der Universität, Kiel, Germany.
L	Rijksherbarium, Leiden, Holland.
LD	Botanical Museum and Herbarium, Lund, Sweden.
LINN	Linnean Society of London, London, England.
LIV	Herbarium, Public Museums, Liverpool, England.
M	Botanische Staatssammlung, München, Germany.
MEL	National Herbarium of Victoria, Melbourne, Australia.
NSW	National Herbarium of New South Wales, Sydney, Australia.
O	Botanisk Museum, Oslo, Norway.
PC	Laboratoire de Cryptogamie, Musêum d'Histoire Naturelle, Paris, France.
S	Naturhistoriska Riksmuseum, Stockholm, Sweden.
TCD	School of Botany, Trinity College, Dublin, Eire.
TRH	Botanical Department, Museum of the Royal Norwegian Society, Trondheim, Norway.
UC	Herbarium, University of California, Berkeley, California, U.S.A.
UPS	Botaniska Museet, Uppsala Universitet, Uppsala, Sweden.
W	Naturhistorisches Museum, Wien, Austria.

Notes on the Location and State of Types of Southern Australian Marine Algae

The following list of authors includes all who have described more than a very few southern Australian marine algae. Authors of one or a few species or of some cosmopolitan species are excluded, and information is given under the particular species.

Agardh, C. A.—The Agardh herbarium (C. A. and J. G. Agardh) is housed as a separate unit in the Botaniska Museet, Lund, Sweden (LD). The collection is maintained exactly as left by J. G. Agardh, but each specimen or sheet of notes is numbered. C. A. Agardh's types are often small and fragmentary. Many were described from specimens (of Montagne, Desfontaisnes, Gaudichaud, etc.) in the Paris Museum (PM), and the best specimen is often here; Agardh presumably was given or kept part of the original specimen, though in some cases no specimen could be located in PM. Agardh's species were nearly always described from a single specimen.

Agardh, J. G.—His collections form the bulk of the Agardh herbarium in Lund, and comprise the second most important collection of Australian algal types. In many cases where there are several collections under a species, more than one species is present, and in all cases it is necessary to locate or choose the type, on which the specific concept can be fixed. This has been done, and the type numbers are given below under the species. Much of J. G. Agardh's material was very inadequate, and often his specific concepts were not good. As a result he tended to be a "splitter", and often described a species under different names, especially in the Rhodophyta. J. G. Agardh's studies, based entirely on dried material and without having ever seen Australian algae in the field, were remarkable for their thoroughness, but much taxonomic revision of the Australian material is now necessary.

Areschoug, J. E.—The Australian types of Areschoug are in the Botanical Department, Riksmuseet, Stockholm, Sweden (S). The specimens are mostly reasonably good ones.

Bornet, E.—See under "Paris Museum".

Bory de St. Vincent, J. B. M.—See under "Paris Museum".

Brown, R.—Brown's main collections are at the British Museum (Natural History), South Kensington, London (BM). No Australian marine algae were described by Brown, but these were passed over to Dawson Turner. Turner's figures are usually accurate representations of the type specimen, which can be well matched (but are reversed in printing). The Australian types credited to Brown by Turner are mostly in BM, but sometimes are in Kew (K) (i.e. the Kew specimen is the one Turner figured). Isotypes of most are at Kew, and other duplicates are in the herbarium (E) of the Royal Botanic Gardens, Edinburgh, Scotland (herb. Greville). The specimens in BM are in good condition, the types in separate folders.

Crouan, P. L., and Crouan, H. M.—Their collection is said to be at Concarneau, France. Only two Australian species are involved, and an authentic (type?) specimen of one (*Ophidocladus simpliciusculus*) is in the herbarium Thuret-Bornet, PM.

Decaisne, J.—See under "Paris Museum".

Derbes, A., and Solier, A.—Their collection is supposed to be at Marseilles, France, but the Botanical Department of the University there knows nothing of it. The only species from Australia involved is *Giraudya sphacelarioides;* no type of this could be found in PM.

Dillwyn, L. W.—Several cosmopolitan species, described by Dillwyn from England, occur in Australia. The types of these have not been located. In the Linnean Society, London, are four thin books named "British Confervae. Fasc. I–IV", and these contain most of the species figured by Dillwyn in plates 1–38, but none figured in later plates.

Esper, E. J. C.—Esper's Australian species were described from specimens sent him by Turner, and in most cases the figures are poor and based on fragments only. Esper's specimens are supposed to be in the Botanical Institute, the University, Erlangen, Germany (ER), but enquiries have brought to light only one species. There is no apparent way of checking from material in Kew, which specimens were sent to Esper by Turner. An account of Esper's work is given by Silva (1953).

Falkenberg, P.—Several Australian Rhodomelaceae and Dasyaceae were described by Falkenberg from collections borrowed from various herbaria. These will be dealt with under each species.

Foslie, M. H.—All Foslie's species and varieties of Australian coralline algae were located in his collections at the Trondheim Museum, Norway (TRH), except var. *australasica* of *Goniolithon elatocarpon*. The specimens are in good condition, with full collection data on the boxes. Foslie did not specify types, but in all cases the collection used by Foslie (made before his published description) was located. Owing to the abundant collections in most cases, isotype specimens were kindly presented to the writer and are now deposited in AD.

Gepp, A., and Gepp, E. S.—These types are all in BM and are well preserved in type folders.

Greville, R. K.—All Greville's Australian types are in E, and are all in good condition. These specimens probably all came from Fraser, who collected near the Swan River, W.A.; this is given on many but not all of the specimens.

Grunow, A.—Grunow's collections are in the Botanischen Abteilung, Naturhistorischen Hofmuseum, Wien, Austria (W), and are in good condition. Grunow's Australian types are mostly species and varieties of *Sargassum* from northern Australia.

Harvey, W. H.—The herbarium of W. H. Harvey is of first importance to Australian algologists. All except two of his Australian species were located in the Herbarium of the Botany Department, Trinity College, Dublin, Eire (TCD). The condition of the specimens is generally good, and types have been marked as such by the writer. Harvey used two distinct series of numbers on his Australian specimens:

(1) Numbered specimens in his travelling sets (originally in books, now incorporated in the herbarium proper). These numbers, mainly of Western Australian algae, are given in his (1854) account, and must apply to the types of the species concerned. Unfortunately many of the specimens had been previously torn out of the travelling sets; some were in the herbarium, but many are missing. Where they are missing, a specimen of the same collection in the herbarium was taken as the type.

(2) Numbers used in his "Algae Australiae Exsiccatae", with a letter for the locality.

Hooker, J. D.—Hooker's collection is at the Royal Botanic Gardens, Kew, England (K). The Australian species were probably all described by W. H. Harvey, and the main specimen is usually in Kew. Isotypes are frequently found in Harvey's collections at TCD, and in some cases the true type may be here. Hooker's specimens are generally in good condition, in type folders.

Hudson, G.—Only cosmopolitan species, mostly well known, are involved here. Hudson's types are mostly lost, but a type specimen of *Plocamium coccineum* is in BM.

Kjellmann, F.—The Australian *Galaxaura*'s described by Kjellmann are either in herb. Areschoug (S) or in Herbarium Uppsaliensis, Botanical Institute, Uppsala, Sweden (UPS). In several cases the species are based on very poor fragments, and some uniting of so-called species is necessary.

Kützing, F. T.—Most of Kützing's types of Australian algae are in the Rijksherbarium, Leiden, Holland (L), but many he described from herbarium Sonder, which is in Melbourne National Herbarium, Australia (MEL). The types in L are all well and carefully preserved, and marked as such. Many of Kützing's specimens, however, were small and not very adequate. Sometimes a specimen from herbarium Sonder is represented by a small fragment in L. Kützing's figures in "Tabulae Phycologicae" are generally fairly good of the specimens available, and he referred to his description and figure on the particular specimen sheet. This makes his types easy to identify.

Labillardiere, J. J.—The nine species of brown and red algae, comprising the first descriptions of Australian algae, are in the Herbarium Universitatis Florentinae, Firenze, Italy (FI).

Lamarck, J. B. de.—See under "Paris Museum".

Lamouroux, J. V. F.—His herbarium is at the Botanical Institute, Caen, France (CN). Most, but not all, of the Australian types were located there, and Lamouroux' original labels are usually with the specimens. Some specimens are good, others inadequate. In a few cases there is isotype material in the General Herbarium, PM.

Lenormand, S. R.—Lenormand did not describe any Australian species, but the three species described from his herbarium are at CN. Two of these were also located at PM.

Levring, T.—His Australian collections, made during 1948, are in his personal herbarium, Marinbotaniska Institut, Goteborg, Sweden. The types of his smaller species are kept as slides or in alcohol. Isotypes of all his new species of Bangiales and Nemalionales are also at AD.

Linnaeus, C.—The main collections of Linnaeus are in the Linnean Society of London, England (LINN). Specimens of many, but not all, of Linnaeus's species which occur in Australia are there, but there is some doubt whether these are always the original specimens, and not later replacements.

Lucas, A. H. S.—The Lucas herbarium is owned by the Division of Plant Industry, C.S.I.R.O., Canberra, but is on loan to the National Herbarium of New South Wales, Sydney, Australia (NSW). Lucas's species are usually represented by a good series of specimens, and an isotype series is at AD.

Mertens, F. C.—See under "Paris Museum".

Montagne, J. F. C.—See under "Paris Museum".

Mueller, F. von.—F. von Mueller's collections were described by other workers, and are located in the herbarium concerned. Many specimens, however, are at MEL.

Müller, O. F.—The species involved here are cosmopolitan ones, described in 1778, and probably no authentic specimens were kept. It seems best to use specimens from the type localities for comparison.

Paris Museum

Collections of numerous French authors are housed at the Laboratoire de Cryptogamie, Muséum National d'Histoire Naturelle, 12 Rue Buffon, Paris 5e (PC). The collections are divided into:

(1) Herbarium Thuret-Bornet, which includes material of these two authors and of Bory de St. Vincent, and some other old specimens.
(2) Herbarium Sauvageau.
(3) Herbarium Montagne.
(4) France herbarium.
(5) General herbarium—the remaining collections.

Some trouble was experienced in locating specimens, as many are loose and the types are not marked. The following authors of Australian specimens are represented in the collections:

Agardh, C. A. Agardh received and described numerous specimens from PM, collected by Desfontaisnes, Gaudichaud, and others on French expeditions. While the actual type may be in Lund, in some cases better specimens are in the general herbarium (5), and a few species may only be represented in the latter.

Bornet, E. The type specimen of the single species of Bornet which occurs in southern Australia is in the Thuret-Bornet herbarium (1).

Bory de St. Vincent, J. B. M. All Bory's specimens were located in (1).

Decaisne, J. His specimens are in (5); most but not all were located.

Lamarck, J. B. de. Lamarck described four species of corallines which occur in southern Australia, and a single, rather fragmentary specimen of each was located in (5).

Mertens, F. C. Mertens, a Danish algologist, described a number of species from (5). In most cases, but not all, the type was located, some being found amongst unsorted "indeterminata". The specimens were variable in quality, but had Mertens's original label with them. Some species credited to Mertens were described by Turner.

Montagne, J. F. C. All the required specimens were located in herbarium Montagne (3).

Quoy and Gaimard. The type specimen of *Acetabularia calyculus* was not found at PM.

Rosanoff, S. Rosanoff described two Australian corallines from herb. Lamouroux, and these were located in herbarium Lamouroux in CN.

Sauvageau, C. Some of Sauvageau's species (of Sphacelariales) were described from other herbaria (e.g. TCD) in which case fragments only are in herbarium Sauvageau (2). Original specimens and others examined by Sauvageau are clearly indicated with his attached annotation labels.

Quoy and Gaimard.—See under "Paris Museum".

Reinbold, T.—The main herbarium of Reinbold is at the Botanical Museum, Menzingerstrasse 13, München 38, Germany (M), and most of his Australian specimens were seen (on loan). Some isotypes are in the Rijksherbarium, Leiden (L), and others in AD.

Reinke, J.—His collections are in the Botanisches Institut der Universität, Kiel, Germany (KIEL). During the war they were crated and have not yet been available for study.

Rosanoff, S.—See under "Paris Museum".

Roth, A. W.—Roth's collections were in Berlin, but are reported to have been lost during the Second World War.

Sauvageau, C.—See under "Paris Museum".

Setchell, W. A.—Setchell's herbarium, including the types of three Australian species, are in the Department of Botany, University of California (UC).

Sonder, O. W.—Sonder's herbarium is incorporated in MEL. The types are usually easily selected from Sonder's notes and accompanying drawings. Sonder's herbarium includes many species described by Kützing.

Suhr, J. N.—Some, but not all, of Suhr's types are at L.

Turner, D.—Turner's Australian species were mostly collected by Robert Brown, and in many cases the name is credited to Brown by Turner. In nearly all cases a specimen which matches Turner's figure was found, either at K or at BM. Turner's collections are housed at K, Brown's at BM. Turner also described some specimens received from Mertens from PM. These were credited to Mertens, but in some cases it is not certain whether Turner's or Mertens's description has priority, being published in the same year. Mertens's specimens which were figured by Turner are at K. All Turner's type specimens are in good condition, and labelled as such.

Velley, T.—Velley's types of three Australian species are preserved in the Herbarium, Public Museums, Liverpool, England (LIV).

Weber van Bosse, A.—The three Australian *Caulerpa* described by Weber van Bosse were from other herbaria than her own, which is now housed in Leiden.

Wilson, J. B.—Wilson's specimens, from the vicinity of Port Phillip, Victoria, were described by J. G. Agardh, and the types are at LD. Other representative collections are found at MEL and at BM.

Zanardini, G.—Zanardini described a considerable number of Australian species, now preserved in the Museo Civico Correr, Venezia, Italy. Many of these have been seen, on loan at BM, but others represented by only one specimen are not sent on loan, and remain virtually unknown.

Order CHLOROCOCCALES

Family CHLOROCOCCACEAE

Genus CODIOLUM Braun

Codiolum kuckuckii Skottsberg & Levring in Levring 1941: 604, fig. 1A.

Type locality.—Juan Fernandez I. (Skottsberg) (presumably, though other localities given). *Type.*—Skottsberg herbarium (probably at S).

Distribution.—Epiphytic in *Splachnidium rugosum*; South Africa, New Zealand, Juan Fernandez and San Felix Is., and southern Australia (no localities given by Levring, but *Splachnidium* occurs sporadically in southern Australian waters, mainly on granite or Pre-Cambrian rocks).

Order ULOTRICHALES

Family ULOTRICHACEAE

Genus ULOTHRIX Kützing

Ulothrix pseudoflacca Wille 1900: 22, pl. 2, figs. 64–81. Hamel 1931: 22, figs. 6E, F. Jonsson 1904: 55–7, fig. 7. Kylin 1949: 12. Levring 1944: 2. Setchell and Gardner 1920: 285.

Ulothrix implexa Kützing sensu Womersley 1950: 141.

Type locality.—Drobak, Norway (Wille). *Type.*—O.

Distribution.—Northern Europe; Mediterranean; Alaska to California; Tristan da Cunha; Crozet Is. In Australia, from American River inlet, Kangaroo I.

The American River inlet material agrees well with a specimen of Wille's from Drobak in L. The filaments are 10–11 μ thick, cells $\frac{1}{2}$–$1\frac{1}{2}$ times as long as broad (mostly $\frac{1}{2}$–1), with a thin wall and usually 1 pyrenoid. This material had been previously referred to *U. implexa* Kützing, the type of which is in L (No. 938, 174 . . . 397), labelled "Goes (Zelande) in submarinis. 150" in Lenormand's writing, and "*Ulothrix implexa*" written in ink over "*Hormidium implexum*" by Kützing. However, I could find no trace of a *Ulothrix* in the specimen (nor could Dr. J. Th. Koster after considerable search), which consists almost entirely of a *Rhizoclonium* and diatoms. Kützing's description and figure (1852: 30, pl. 94, fig. 2) are not very good, but in his original description (1847: 177, as *Hormidium implexum*) he refers to "gonidiis (saepe pectinatis) punctato-granulosis". The only thing in the type that this fits are cells of *Melosira* which are present. As no *Ulothrix* could be found in the type of *U. implexa* Kützing, it seems necessary to completely reject this name, as was done by Wille on other grounds.

Order CHAETOPHORALES

Family CHAETOPHORACEAE

Genus ENTOCLADIA Reinke

Entocladia viridis Reinke. Levring 1946: 216. Setchell and Gardner 1920: 289. Smith 1944: 35.

Endoderma viride De Toni 1889: 209.

Type locality.—Naples, Italy (in *Derbesia lamourouxii*). *Type.*—Germany?

Distribution.—Probably cosmopolitan. Recorded by Levring from "Sydney" and "Melbourne", epiphytic in *Lomentaria australe* and *Hymenema curdieana*, but probably much more widespread along southern Australia.

Order ULVALES

Family ULVACEAE

Genus BLIDINGIA Kylin

Blidingia minima (Naegeli in Kützing) Kylin 1947: 181; 1949: 30, figs. 30, 31. Womersley 1950: 142; 1953: 36.

Enteromorpha minima Naegeli in Kützing 1849: 482; 1856: 16, pl. 43, fig. 3. Bliding 1938: 84, figs. 1–6. Doty 1947: 17. Sjostedt 1939: 18, fig. 1.

Enteromorpha nana (Sommerfelt) Sjostedt 1939: 29, fig. 4.

Enteromorpha gunniana J. Agardh 1883: 122. De Toni 1889: 119. Guiler 1952: 73. Lucas 1912: 165; 1928: 9. Sjostedt 1939: 54, fig. 11.

Type locality.—Heligoland, Germany (Naegeli). *Type.*—L.

Distribution.—Probably almost cosmopolitan. In Australia, known from the Recherche Archipelago, W.A.; Kangaroo I. and Outer Harbour, S.A.; Bridgewater Bay, Vic.; Georgetown and Thonin Bay, Tas. Probably it is generally distributed, though spasmodic, along southern Australia.

The type of *E. gunniana* is in LD (herb. Agardh, No. 13412) and appears cospecific with *B. minima*. Sjostedt has previously discussed their very close relationships. The only apparent difference lies in the more massive basal layer, from which tubular fronds arise, in *E. gunniana*.

Genus ENTEROMORPHA Link

Few genera are as troublesome as *Enteromorpha*. The systematics of the genus are still very confused, largely owing to the limitations of dried material. The most satisfactory recent work is that of Bliding, who has used living material, studying the cell morphology—arrangement, size, and pyrenoids—and experimentally testing conjugation between gametes from apparently different forms. In *E. clathrata* Bliding has shown that three morphological forms occur, but are all inter-fertile; these forms (and others) had previously been regarded as distinct species.

Until cultural studies similar to Bliding's can be made on southern Australian forms of *Enteromorpha*, the species occurring in Australia must remain doubtful. Bliding's concepts based on cell morphology can be used for a rough grouping, and this has been done below. Dried material is often virtually useless, but liquid-preserved specimens have been available from many South Australian collections. As the type specimens of nearly all species are dried, it seems best to follow Bliding's concepts and application of the names. Culture work is also needed to determine whether any of the species newly described by Bliding occur in Australia. It is likely that his *E. ahlneriana* does occur, but confirmation is needed. *E. kylinii* may also occur.

The references given below include only those involving Australian records and some of the most useful ones to the cosmopolitan species.

Enteromorpha acanthophora Kützing 1849: 479; 1856: 12, pl. 34, fig. 1. J. Agardh 1883: 157. De Toni 1889: 135. Guiler 1952: 72. Lucas 1912: 166; 1928: 9.

Type locality.—New Zealand (Hooker). *Type.*—L (No. 938, 19 . . . 134).

Distribution.—New Zealand. Other records doubtful.

This species was recorded from Tasmania (R. Gunn) by J. Agardh, Guiler, and Lucas, and from Kangaroo I. by Womersley (1950: 142). I have seen Kützing's type and the Kangaroo I. specimens are clearly different; probably they are forms of *E. clathrata*. The Tasmanian specimens have not been seen. In other collections I have not seen specimens identical with the New Zealand *E. acanthophora*, and whether this species occurs in Australia must be regarded as doubtful.

Enteromorpha ahlneriana Bliding 1944: 338, figs. 10–18. Doty 1947: 15. Kylin 1949: 26, figs. 21–24.

Bliding described this species from Sweden on the basis of culture work on living material. Included under it are some forms previously referred to *E. procera*. Bliding (1944: 355) considers the name *E. procera* should be abandoned, as Ahlner's original figure shows cell arrangement as in the *E. compressa-intestinalis* group. Bliding believes *E. ahlneriana* is probably represented amongst specimens from American River inlet, Kangaroo I., sent him by the writer. Further confirmation is needed to establish this record.

Guiler (1952: 73) records *E. procera* forma *subundulata* Schiff. from Tasmania, on Chapman's determination, with no details. This may or may not be a form of *E. ahlneriana*.

Enteromorpha bulbosa (Suhr) Montagne 1846: 3. J. Agardh 1883: 139. De Toni 1889: 127. Guiler 1952: 72. Kützing 1849: 482. Levring 1944: 3, figs. 1*c-f*. Lucas 1912: 165; 1928: 9. Taylor 1938: 130; 1947: 59. Wilson 1892: 189.

Solenia bulbosa Suhr 1839: 72, pl. 4, fig. 46.

Enteromorpha novae-hollandiae Kützing 1856: 14, pl. 38, fig. 3?

Type locality.—Peru. *Type.*—L.

Distribution.—West coast of South America; sub-antarctic regions. Recorded from Tasmania by J. Agardh and by Kützing (as *E. novae-hollandiae*). I have not been able to check these records.

Chapman (1949: 496, fig. 3) described *E. bulbosa* forma *foliacea* from specimens from American River inlet, Kangaroo I. (not "R.I., Adelaide" as in description) sent him by the writer. The cells are arranged in rows in the lesser branches, partly so in older parts, and are 15–30 μ across in surface view of mature parts, with 2 or 3 pyrenoids per cell. Chapman's description is not accurate; the main thallus is scarcely compressed and his measurements are faulty (and some apparently misprinted). Bliding regards these specimens as a form of *E. clathrata*, with which I agree. This form is only one of many at American River inlet which are referable to *E. clathrata*.

The concept of *E. bulbosa* needs clarification. The type (in L) has cells mostly 8–12 μ across (slightly larger in older parts) in surface view, irregularly arranged, whereas Taylor (1947) gives "cells to 15–22 μ diam". Levring's (1944: 3, figs. 1*c–f*) concept appears to agree with the type.

Enteromorpha clathrata (Roth) Greville 1830; 181. J. Agardh 1883: 153. Bliding 1933: 236; 1944: 331, figs. 1–9. De Toni 1889: 133. Doty 1947: 16. Guiler 1952: 73. Harvey 1863: synop. 760. Kylin 1949: 28, figs. 27–29. Lucas 1912: 166; 1928: 9; 1936: 23. Reinbold 1897: 44. Sonder 1852: 659; 1853: 506; 1880: 40. Wilson 1892: 189. Womersley 1950: 142.

Enteromorpha ramulosa (Smith) Hooker. J. Agardh 1883: 154, pl. 4, figs. 117–118. De Toni 1889: 134. Guiler 1952: 73. Harvey 1851: pl. 245. Lucas 1912: 166; 1928: 9.

Desmotrichum plumosum Sonder 1852: 662.

Schizogonium pallidum Kützing. Tate 1882: 93?

Enteromorpha lingulata J. Agardh 1883: 143. De Toni 1889: 128. Guiler 1952: 73. Lucas 1912: 165; 1928: 9. May 1938: 211. Wilson 1892: 189.

Enteromorpha hopkirkii sensu Wilson 1892: 189.

Enteromorpha crinita sensu Reinbold 1898: 33. Lucas 1936: 23.

Enteromorpha bulbosa forma *foliacea* Chapman 1949: 496, fig. 3 (see under *E. bulbosa*).

Enteromorpha acanthophora sensu Womersley 1950: 142 (not Kützing).

Type locality.—Europe. *Type.*—Probably not in existence.

Distribution.—Cosmopolitan.

Bliding recognizes three forms of this species, the third of which is often known as *E. plumosa*. *E. clathrata* is probably the commonest species along southern Australia, occurring almost everywhere in one form or another. *E. ramulosa* was described by Smith from Bantry Bay, Ireland, and recorded from Tasmania by J. Agardh. The type is in K. Cotton remarks on the species folder that it is *E. clathrata*, with which I agree.

J. Agardh gave several localities, including Tasmania, in his description of *E. lingulata*. This species has been recognized by some other workers (e.g. Newton 1931: 69) but the cell form appears to fall within that of *E. clathrata*. The Australian specimens from Georgetown, Tas., in LD, appear to be forms of *E. clathrata*. May places *E. lingulata* under the group with cells not in longitudinal rows, but this is at variance with J. Agardh's conception. May's New South Wales specimens appear more like *E. compressa*.

E. opposita J. Agardh was published as a nomen nudum by Wilson (1892: 189). Two of Wilson's specimens from Western Port and Port Phillip Heads are in MEL. It is scarcely possible to determine them with any certainty, but they may be forms of *E. clathrata*.

Enteromorpha compressa (Linnaeus) Greville 1830: 180. J. Agardh 1883: 137. Bliding 1948: 128, figs. 6–9. De Toni 1889: 126. Doty 1947: 14. Guiler 1952: 73. Harvey 1844: 454; 1854: 566; 1860*b*: 341; 1863: synop. 759. Hooker and Harvey 1847: 417. Kützing 1849: 480. Kylin 1949: 22, figs. 14–15. Lucas 1912: 165; 1928: 9; 1936: 23. May 1938: 211. Reinbold 1897: 44. Sonder 1852: 659; 1853: 506; 1880: 40. Womersley 1950: 142.

Enteromorpha chlorotica J. Agardh 1883: 136. De Toni 1889: 125. Lucas 1912: 165.

Type locality.—Sweden. *Type.*—LINN.

Distribution.—Cosmopolitan.

The type of *E. chlorotica* is in LD (No. 14029, with a few other specimens), from Swan River, W.A. The type consists of several thalli, branched near the base, widening to about 1 cm above. The cells are fairly large and irregularly arranged. J. Agardh separated *E. chlorotica* from *E. compressa* because of its pale colour, but there seems to be no justification for this; such bleached drift specimens of *E. compressa* are of frequent occurrence.

Enteromorpha flexuosa (Wulfen in Roth) J. Agardh 1883: 126. De Toni 1889: 121. Guiler 1952: 73. Lucas 1912: 165; 1928: 9. Wilson 1892: 189.

Type locality.—Adriatic Sea. *Type.*—Probably not in existence.

Distribution.—Widely distributed according to J. Agardh and recorded by him from Tasmania (coll. R. Gunn). I have not seen this specimen, and both the record and relationships of *E. flexuosa* need clarification.

Enteromorpha intestinalis (Linnaeus) Link. Bliding 1948: 123, figs. 1–4. De Toni 1889: 123. Doty 1947: 14. Guiler 1952: 73. Harvey 1860*b*: 341. Kylin 1949: 22, fig. 13. Levring 1946: 215. Lucas 1928: 9; 1936: 23. May 1938: 211. Sonder 1880: 40. Womersley 1950: 142.

Type locality.—Sweden. *Type.*—? (Not in LINN.)

Distribution.—Cosmopolitan, probably occurring generally around southern Australia.

Bliding separates *E. intestinalis* as being unbranched while *E. compressa* is branched. If this distinction is strictly upheld, relatively few collections from southern Australia are referable to *E. intestinalis*, as the thalli in most specimens of this group are branched at least a very few times near the base.

Enteromorpha linza (Linnaeus) J. Agardh 1883: 134, pl. 4, figs. 110–112. Bliding 1933: 234; 1939: 139, figs. 4–7. De Toni 1889: 124. Doty 1947: 18. Guiler 1952: 73. Kylin 1949: 19, fig. 12. Lucas 1912: 165; 1928: 9.

Ulva linza Linnaeus. Harvey 1851: pl. 39. May 1938: 211.

Type locality.—Europe. *Type.*—? (Not in LINN.)

Distribution.—Widely distributed. Australian records are those of De Toni from Tasmania and May from Port Jackson, N.S.W. I have not seen true *E. linza* on southern Australian coasts, and if it does occur it is probably rare. The old records need checking.

Enteromorpha prolifera (Müller) J. Agardh 1883: 129, pl. 4, figs. 103–104. Bliding 1933: 240; 1939: 134, figs. 1–3. De Toni 1889: 122. Doty 1947: 14. Guiler 1952: 73. Kylin 1949: 25, fig. 20. Levring 1946: 215. Lucas 1928: 9. May 1938: 211.

Type locality.—Lolland, Denmark. *Type.*—Not in existence.

Distribution.—Widely distributed. This species probably occurs along the southern Australian coast generally, but is not common. Critical work is needed, however, on Australian specimens called *E. prolifera*, following Bliding's concepts.

Genus ULVA Linnaeus

Ulva lactuca Linnaeus. C. Agardh 1821: 409. De Toni 1889: 111. Guiler 1952: 72. Harvey 1863: synop. 758. Kylin 1949: 17, fig. 11. Levring 1946: 215. Lucas 1912: 165; 1928: 9; 1936: 22. May 1938: 211. Setchell and Gardner 1920: 265. Sonder 1852: 659; 1853: 506. Womersley 1950: 141.

Ulva latissima C. Agardh 1821: 407. Harvey 1844: 454; 1860*b*: 342; 1863: synop. 756. Hooker and Harvey 1847: 417. Lucas 1912: 165. Sonder 1880: 39.

Phycoseris ulva Sonder 1845: 49; 1846: 153; 1852: 659; 1853: 506. Harvey 1854: 565. Kützing 1849: 477.

Phycoseris gigantea var. *perforata* Kützing 1849: 476.

Phycoseris latissima Harvey 1854: 565.

Ulva australis Areschoug 1854: 370. Sonder 1880: 39.

Ulva laetevirens Areschoug 1854: 370. J. Agardh 1883: 167. De Toni 1889: 114. Guiler 1952: 72. Lucas 1912: 165; 1928: 9; 1936: 22. May 1938: 211. Sonder 1880: 40.

Ulva rigida J. Agardh 1883: 169. Harvey 1863: synop. 757. Levring 1946: 215. Reinbold 1897: 44. Sonder 1880: 39.

Type locality.—Sweden. *Type.*—LINN.

Distribution.—Cosmopolitan.

The great majority of the forms of *Ulva* along southern Australia can probably be classed under *U. lactuca*. Some authors (e.g. Setchell and Gardner) have recognized several segregate species, but until culture work similar to Bliding's on *Enteromorpha* can be carried out on the forms of *Ulva* it seems best to lump the intergrading forms under *U. lactuca*. The type of *Phycoseris ulva* Sonder is in MEL and is only a small specimen of *U. lactuca*.

The type of *Phycoseris gigantea* var. *perforata* Kützing is in L (No. 938, 19 . . . 34) and appears to be fairly typical *U. lactuca*.

The type of *Ulva australis* Areschoug (from Port Adelaide, S.A.) is in S and comprises four similar specimens on one sheet. They appear to be only a stout and thicker form (especially at the base) of *U. lactuca*. The type of Areschoug's *U. laetevirens* from Port Phillip is also in S, but again appears to be *U. lactuca* with a broadly expanded thallus.

Tepper (1883: 66) recorded *Letterstedtia australis* as a nomen nudum, based on a determination by J. G. Agardh. This specimen is in an old collection in AD and appears to be only a very poor fragment of *Ulva lactuca*.

Ulva petiolata (J. Agardh) comb. nov.

Letterstedtia petiolata J. Agardh 1883: 176, pl. 4, figs. 123–124. De Toni 1889: 139. Lucas 1912: 166; 1936: 22.

Type locality.—Port Phillip, Vic. (F. von Mueller, on stems of *Cymodocea*). *Lectotype.*—LD (herb. Agardh, No. 14551).

Distribution.—Port Phillip, Vic.; Point Sinclair (east part of Great Australian Bight), S.A.; Port Jackson and Lake Illawarra, N.S.W. (in MEL).

This species has long and narrow (1–3 mm wide) stipes in mature plants, with expanded terminal parts. In the stipes (which may be up to 6 cm long) rhizoid development is considerable; the stipe may reach 500 μ in thickness, with the rhizoids traversing a central space between the cell rows. This stipe and rhizoid development is greater than in most species of *Ulva*, but is only a further development of the trend seen in some.

The generic distinctness of *Letterstedtia* is doubtful and it seems best to refer *L. petiolata* to *Ulva*. *U. petiolata* is common on very rough reefs at Point Sinclair but has not been found in similar localities eastwards in South Australia.

Ulva reticulata Forskål

U. reticulata was recorded by Guiler (1952: 72) from "Tasmania" on a personal communication by Chapman. No details or support for this are given, and the specimen is not in HO. In the absence of any evidence for this record it should not be accepted as a southern Australian marine alga.

U. reticulata is typically a tropical species which may occur on the Queensland coast.

Order SCHIZOGONIALES

Family SCHIZOGONIACEAE

Genus GAYELLA Rosenvinge

Gayella polyrhiza Rosenvinge 1893: 937, figs. 45–46. Hamel 1931: 18, fig. 5. Knebel 1936: 52, fig. 27. Setchell and Gardner 1920: 280.

Type locality.—Goothalb, Greenland (Rosenvinge). *Type.*—C.

Distribution.—Greenland; Alaska; Faroes. In Australia, from American River inlet and Pennington Bay on Kangaroo I., occurring near shag or penguin colonies, above high tide level but subject to salt spray.

In C are three sheets of Rosenvinge's original collection and also some preserved material. The Kangaroo I. specimens seem identical with Rosenvinge's in all ways—form, thickness of filaments, and cell size and shape. Although the localities are so far apart, the habitats of the Greenland and Kangaroo I. specimens are similar, and there seems no reason to separate the latter from *G. polyrhiza*.

Some authors consider *Gayella* a form of *Prasiola*, through Knebel maintains *Gayella* as a distinct genus and also recognizes similar forms under *Prasiola crispa*. The Kangaroo I. specimens are always of the *Gayella* form only, never becoming flattened, so this name seems most applicable.

Order CLADOPHORALES

Family CLADOPHORACEAE

Genus CHAETOMORPHA Kützing

Chaetomorpha aerea (Dillwyn) Kützing 1849: 379; 1853: 19, pl. 59, fig. 1. Cribb 1954: 17, pl. 1, fig. 7. De Toni 1889: 272; 1896: 231. Guiler 1952: 73. Harvey 1863: synop. 779. Kylin 1949: 48, fig. 50. Lucas 1912: 166; 1928: 11; 1936: 26, figs. 7 and 9. May 1938: 213. Newton 1931: 92, fig. 60. Setchell and Gardner 1920: 200, pl. 14, figs. 9–11. Sonder 1880: 41. Taylor 1937: 81, pl. 1, figs. 10–12. Womersley 1950: 143.

Conferva aerea Dillwyn 1806: pl. 80. Harvey 1851: pl. 99B.

Type locality.—Cromer, Britain. *Type.*—K. This species was described from specimens sent to D. Turner by Dr. Goodenough, and in Kew are three such specimens, two from Cromer and another without locality but with "*C. aerea*" and "Mr. Dillwyn 1806" on it. These are clearly type material, and the southern Australian plant appears identical with the type.

Distribution.—Almost cosmopolitan. Widely distributed along southern Australia and around Tasmania, being of common occurrence in littoral rock pools.

Chaetomorpha billardieri Kützing 1847: 166; 1849: 379; 1853: 19, pl. 59, fig. 3. De Toni 1889; 275. Lucas 1912: 166.

Type locality.—"Novae Hollandia" (La Billardiere). *Type.*—L (No. 937, 158 . . . 402).

Distribution.—From Esperance, W.A., to American River inlet on Kangaroo I. (but probably more widespread along southern Australia). The type came from either King George's Sound in Western Australia or southern Tasmania, both of which are outside the above range. This species seems characteristic of calm bays and inlets, and in American River inlet forms dense yellowish-green mats in the lower littoral, up to 10 or 20 yards across and 50 or more yards long. The filaments show very occasional branches.

Chaetomorpha capillaris (Kützing) Borgesen 1925: 45, fig. 13. Feldmann 1937: 208, fig. 17.

Rhizoclonium capillare Kützing 1847: 166.
Chaetomorpha implexa Kützing 1849: 376; 1853: 17, pl. 51, fig. 3. Lucas 1912: 166.
Chaetomorpha tortuosa Kützing 1849: 376; 1853: 17, pl. 51, fig. 2. De Toni 1889: 266 (in part).
Chaetomorpha breviarticulata Hauck 1885: 440.
Lola capillaris Hamel 1931: 25, fig. 37, (8).

Type locality.—Nice, south of France. *Type.*—L (No. 937, 155 . . . 45).

Distribution.—Mediterranean and nearby Atlantic Ocean. In Australia, from American River inlet, Kangaroo I., where it forms tangled masses under samphires (*Salicornia*) in the mid and upper littoral. Also from Russell, New Zealand (Lindauer No. 305 as *Ch. tortuosa* Kützing).

The American River inlet specimens agree well with Kützing's type of *Ch. capillaris* and also the figures of Feldmann. Kützing's type has "*Ch. capillaris* Kütz." crossed out and "*Ch. tortuosa*" written below by Kützing, who referred his own *Ch. capillaris* to *Ch. tortuosa*. Borgesen (1925: 45), however, considered Kützing's *Ch. tortuosa* not the same as Dillwyn's original *Conferva tortuosa* (from England and northern Europe) and this has been followed by several other authors. *Ch. tortuosa* (Dillwyn) Kleen and *Ch. capillaris* Kützing are clearly very closely related, and monographic studies are needed to establish their relationships. Kützing's *Ch. implexa* from Granville, Normandy (L, No. 937, 158 . . . 330) appears identical with his *Ch. capillaris*, and *Ch. breviarticulata* Hauck (L, No. 937, 158 . . . 313, ex herb. Hauck, from Pirano, with "*Ch. implexa* Kütz" in Hauck's writing, though it is probably type material of *Ch. breviarticulata*) seems to be the same species.

Chaetomorpha coliformis (Montagne) Kützing 1849: 380; 1853: 20, pl. 62, fig. 2. De Toni 1889: 275. Guiler 1952: 73. Harvey 1863: synop. 778. Lucas 1912: 166; 1928: 9; 1936: 26. Sonder 1880: 40.

Conferva coliformis Montagne 1842: 16; 1845: 5. Harvey 1860*b*: 341.

Type locality.—Toud I., Torres Strait (Durville). *Type.*—PC (herb. Montagne).

Distribution.—Only known from the type locality and from Tasmania (Southport (Stuart) and Triabunna (Cribb)). This is an unusual distribution, but the Tasmanian specimens of Cribb match the type very well. Re-examination of the type locality is indicated.

Ch. coliformis is closely related to *Ch. darwinii* but the upper mature cells are barrel-shaped (about twice as long as broad) in the former and almost spherical in the latter.

Chaetomorpha darwinii (Hooker) Kützing 1849: 380. De Toni 1889: 271. Guiler 1952: 73. Harvey 1860*b*: 341; 1863: synop. 777. Lucas 1912: 166; 1928: 9; 1936: 25, figs. 6 and 8. Reinbold 1897: 44. Sonder 1852: 658; 1853: 506; 1880: 41. Womersley 1950: 143.

Conferva clavata sensu Hooker & Harvey 1847: 416.
Conferva clavata var. *darwinii* Hooker 1847: 493, pl. 192, fig. 1.

Type locality.—Cape Tres Montes, South America (Darwin). *Type.*—K.

Distribution.—Southernmost South America; New Zealand; southern Australia from Venus Bay on Eyre Peninsula to Western Port in Victoria and around Tasmania.

Chaetomorpha indica (Kützing) Kützing 1849: 376. De Toni 1889: 275. Lucas 1912: 166. Tate 1882: 93.

Conferva indica Kützing 1843: 259; 1853: 11, pl. 52, fig. 3.
Chaetomorpha implexa sensu Tate 1882: 93 (not other authors).

Type locality.—Tranquebar, India (Klein). *Type.*—L (No. 936, 249 . . . 72).

Distribution.—Probably widely distributed in the Indian Ocean and West Indian Ocean. In southern Australia, from Coffin's Bay on Eyre Peninsula and Port Adelaide (Tate); Tasmania? (Lucas).

This is a tropical species (occurring on Moreton I., Qld.) found only in some bays along southern Australia. Tate's records (1882: 93) have been checked from the specimens in MEL.

Chaetomorpha brachygona (Harvey 1858*b*: 87, pl. 46*A*; Borgesen 1913: 18; De Toni 1889: 267; Taylor 1928: 60, pl. 4, fig. 12) from Florida and the West Indian region is probably identical with *Ch. indica.*

Chaetomorpha linum (Müller) Kützing 1843: 204; 1849: 378; 1853: 18, pl. 55, fig. 3. Borgesen 1925: 44. Cribb 1954: 17, pl. 1, fig. 10. De Toni 1889: 269. Hamel 1931: 30, fig. 38*E*. Harvey 1851: pl. 150*A*. Kylin 1949: 49. Newton 1931: 91. Taylor 1937: 80, pl. 1, figs. 1 and 2. Womersley 1950: 143.

Conferva linum Müller 1778: 7, pl. 771, fig. 2.

Type locality.—Lolland, Denmark. *Type.*—Probably not in existence.

Distribution.—Europe; east coast of North America. In Australia, from the Bay of Shoals, Kangaroo I.

This material agrees well with the usual concept of *Ch. linum* and with a specimen of Levring's (in AD) from Sweden. The filaments are 290–330 μ thick and the cells about as long as wide.

Chaetomorpha valida (Hooker & Harvey) Kützing 1849: 379. De Toni 1889: 274. Guiler 1952: 73. Harvey 1863: synop. 780. Lucas 1912: 166; 1928: 11. Sonder 1880: 41. Wilson 1892: 190. Womersley 1950: 143.

Conferva valida Hooker & Harvey 1847: 416. Harvey 1855*b*: 263; 1860*b*: 341. Wilson 1892: 190.

Type locality.—Georgetown, Tas. (Gunn 1345). *Type.*—K.

Distribution.—Venus Bay and American River inlet (Kangaroo I.) in South Australia; Port Phillip Heads, Vic.; Tamar Estuary and Port Arthur, Tas. This species appears to be largely confined to calm, shallow bays or inlets. The record of Harvey (1855*b*: 263) from New Zealand needs checking.

Genus CLADOPHORA Kützing

The following is only a survey of what is known of this difficult genus in southern Australia. Several other species occur, probably undescribed. Many Australian specimens have been identified with European species, but most appear to be distinct from the latter. A fuller treatment must wait on monographic studies.

Cladophora bainesii Harvey 1859: pl. 112; 1860*b*: 340; 1863: synop. 767. De Toni 1889: 319. Guiler 1952: 73. Levring 1946: 216. Lucas 1912: 166; 1928: 11. Sonder 1880: 40.

Type locality.—Port Phillip, Vic. (Harvey). *Lectotype*.—TCD.

Distribution.—Port Phillip, Vic.; Georgetown, Derwent Estuary, Tas. Also recorded from St. Vincent's Gulf by Tate (1882: 93). In MEL there is a specimen labelled "*Cladophora Hainesii* H. & M." from "Hallets Cove, T.G.O.T. 12.4.82, Agardh vid. No. 712". I suspect Tate's record is based on this, the specific name being misspelt. However, the plant is not *C. bainesii*.

Cladophora fascicularis (Mertens in C. Agardh) Kützing 1843: 268; 1849: 393; 1853: 26, pl. 90, fig. 2. Borgesen 1940: 34, fig. 10; 1946: 21, figs. 8–10. De Toni 1889: 316. Levring 1941: 610. Vickers 1908: 18, pl. 13. Womersley 1950: 143.

Conferva fascicularis Mertens in C. Agardh 1824: 114.
Cladophora daveyana Reinbold 1899: 40. Lucas 1936: 29.
Siphonocladus nitidula Reinbold 1899: 39.
Cladophora buchingeri sensu Lucas 1912: 167.
Cladophora "*flacada*" Guiler 1952: 73.

Type locality.—West Indies. *Type*.—LD (herb. Agardh).

Distribution.—Widely distributed in warmer Atlantic and Indian Oceans; Chile and Peru; Juan Fernandez I. In southern Australia, probably general, at least from Venus Bay (Eyre Peninsula) eastwards to Queensland, and around Tasmania. Often plentiful in calm bays and inlets.

This species in southern Australia is rather variable, depending on the environment, but at least some forms of the complex agree well with West Indian specimens. The lower cells are 130–220 μ wide, the upper 40–80 μ wide, with rare to frequent opposite branching (often with the branches both lying on one side) and unilateral, curved branching of upper ramuli.

A type specimen of *C. daveyana* Reinbold (No. 199) in AD (also in MEL) is a form of *C. fascicularis*. Reinbold's specimen of *Siphonocladus nitidulus* in M (No. 54633) from Investigator Strait is also *C. fascicularis*. Some of Reinbold's specimens under *S. nitidulus*, however, are very stunted and may be *C. valonioides*.

Lucas's record of "*C. buchingeri*" seems to be a misprint for *C. ruchingeri*, and is apparently based on a specimen of Sonder's named this in MEL. This specimen does not agree with Kützing's figure of *C. ruchingeri*, but is one of the forms here classed under *C. fascicularis*.

The specimens in HO (Rodway Herbarium) which Guiler gave as *C. flacada* (misread for *C. flaccida*) are within this complex.

Cladophora feredayi Harvey 1858*a*: pl. 47; 1860*b*: 339; 1863: synop. 768. De Toni 1889: 323. Guiler 1952: 73. Lucas 1912: 166; 1928: 9. Sonder 1880: 40. Wilson 1892: 190. Womersley 1950: 143.

Cladophora pellucida sensu Harvey 1863: synop. 769. Guiler 1952: 73? Lucas 1912: 166; 1928: 9. Sonder 1880: 40.

Type locality.—Georgetown, Tas. (Harvey). *Lectotype*.—TCD.

Distribution.—From Cottesloe, W.A., to Port Phillip, Vic., and around Tasmania. Harvey's specimens in TCD named *C. pellucida* (No. 583 from Rottnest I.) are identical with his *C. feredayi*. Lindauer has also distributed this species as *C. pellucida* (Alg. Nova-Zelandiae Exsicc. No. 202).

Cladophora gracilis (Griffiths in Harvey) Kützing 1845: 215; 1849: 403; 1854: 5, pl. 23, fig. 2. De Toni 1899: 322. Guiler 1952: 73. Harvey 1851: pl. 18; 1860*b*: 340; 1863: synop. 770. Kylin 1949: 55, fig. 56. Lucas 1912: 166; 1928: 9. Setchell and Gardner 1920: 216. Sonder 1880: 40.

Type locality.—Tor Abbey, England. *Type.*—TCD.

Distribution.—Northern Europe. Recorded from Tasmania by Harvey. Whether the Tasmanian plants are specificially identical with the English is doubtful. No Australian specimens were located in herb. Harvey, TCD.

Cladophora harveyi nom. nov.

Cladophora gracillima Harvey 1860*b*: 340; 1863: synop. 771. De Toni 1889: 323. Guiler 1952: 73. Lucas 1912: 166; 1928: 9. Sonder 1880: 40.

Type locality.—Georgetown, Tas. (Harvey). *Type.*—TCD. Isotype in MEL.

Distribution.—Only known from the type locality.

The earlier *C. gracillima* Kützing (1849: 400) from England necessitates the renaming of this species. It is distinguished by the excessive fineness of the ramuli (30–45 μ thick below, 10–20 μ thick above, with rather distinct branching).

Cladophora repens (J. Agardh) Harvey 1851: pl. 236. De Toni 1889: 345. Hamel 1928: 70, fig. 19*C*. Kützing 1849: 416; 1854: 15, pl. 70, fig. 2. Newton 1931: 87. Womersley 1950: 143.

Conferva repens J. Agardh 1842: 13.

Cladophora acrosiphonia J. Agardh in Wilson 1892: 190.

Type locality.—Mediterranean. *Type.*—LD (herb. Agardh).

Distribution.—Mediterranean, Europe. In Australia, from Kangaroo I., and Western Port and Port Phillip in Victoria.

These specimens agree so well with the type (and also with a Kützing specimen from Genoa, in AD) that they must be considered co-specific. They are superficially similar to *Cladophoropsis membranacea* (Agardh) Borgesen, but whereas the latter does not have cross walls at the base of the branches, *C. repens* normally does, though the cross wall is sometimes a short distance above the branch base. Rhizoids, 1–3 cells long, are occasionally present in the Kangaroo I. specimens.

Very similar specimens, but slightly more slender with shorter cells and usually no rhizoids, are fairly common on other parts of the southern Australian coasts. This may be a form of *C. repens*.

The Western Port and Port Phillip Heads specimens of Wilson (in MEL) had apparently been determined by J. G. Agardh as belonging to the *Acrosiphonia* group.

Cladophora rugulosa Martens 1866: 112, pl. 2, fig. 3. De Toni 1889: 306. Papenfuss 1943: 79.

Apjohnia rugulosa Murray 1891: 209, pl. 52, fig. 5.

Type locality.—Port Natal, South Africa (Krauss). *Type.*—?

Distribution.—South Africa; Japan. Also from Rottnest I., W.A. (A. B. Cribb in AD). This collection, from lower littoral pools in a limestone ramp, is the first Australian record, but agrees very well with South African material of Papenfuss and a specimen from Natal in AD.

Cladophora stuartii Harvey 1860*b*: 340; 1863: synop. 772. De Toni 1889: 313. Guiler 1952: 73. Lucas 1912: 166; 1928: 9. Sonder 1880: 40.

Type locality.—Tasmania (Stuart). *Type.*—TCD.

Distribution.—Only known from the type collection and one from "mouth of the Huon" in MEL.

Cladophora valonioides Sonder 1845: 49; 1846: 149; 1880: 40. De Toni 1889: 308. Guiler 1952: 73. Harvey 1854: 565; 1859: pl. 78; 1863: synop. 773. Kützing 1849: 391; 1853: 25, pl. 85, fig. 1. Lucas 1912: 166; 1936: 27, fig. 10. Womersley 1950: 143; 1953: 36.

Cladophora nitidula Sonder 1845: 49; 1846: 149; 1880: 40. De Toni 1889: 308. Harvey 1863: synop. 774. Kützing 1849: 391; 1853: 25, pl. 84, fig. 2. Lucas 1912: 166; 1936: 27.

Cladophora conformis Reinbold 1898: 34. Lucas 1936: 28.

Siphonocladus valonioides Reinbold 1899: 41.

Siphonocladus nitidulus Reinbold 1899: 41 (in part, also = *C. fascicularis*).

Type locality.—Western Australia (Preiss). *Type.*—MEL.

Distribution.—From Champion Bay, W.A., to Portland, Vic.

The type material of *C. conformis* Reinbold is in M and is normal and fairly well-developed *C. valonioides*. The type of *C. nitidula* Sonder (in MEL) is a loosely branched form of *C. valonioides*.

SPECIES OF CLADOPHORA INCORRECTLY RECORDED FROM SOUTHERN AUSTRALIA

Cladophora callicoma Kützing 1843: 267.

Recorded by Tate (1882: 93) (and Lucas 1912: 166) from St. Vincent's Gulf, S.A., based on an F. v. Mueller collection determined by J. G. Agardh. This, however, is a freshwater species. There is no marine specimen under this name in MEL.

Cladophora ceratina Kützing 1843: 267.

Recorded by Womersley (1950: 142) from Kangaroo I. Comparison with the type material of Kützing (in L) shows that this record is not correct.

Cladophora crispata (Roth) Kützing 1843: 264.

Recorded by Tate (1882: 93) (and Lucas 1912: 167) from St. Vincent's Gulf, S.A., based on a Tepper collection determined by J. G. Agardh. This is a freshwater species which extends into brackish water, but is not truly marine. The specimen on which this record was based has not been located.

Cladophora crystallina (Roth) Kützing 1845: 213.

Recorded by Tate (1882: 93) (and Lucas 1912: 167) from Holdfast Bay, S.A., based on an F. v. Mueller collection determined by J. G. Agardh. This is the only Australian record of *C. crystallina* and open to doubt. The specimen has not been located, but until the presence of this European species in Australia is confirmed, it is best excluded from the algal flora.

Cladophora delicatula Montagne 1850: 302.

Recorded by Womersley (1950: 143) from Kangaroo I. Examination of the type (PC, herb. Montagne) from South America shows that the Kangaroo I. specimen is not *C. delicatula*.

Cladophora ferruginea Harvey 1860*b*: 340; 1863: synop. 775. De Toni 1889: 337. Guiler 1952: 73. Lucas 1912: 166; 1928: 9. Sonder 1880: 40.

This species, found on *Hormosira* at Port Arthur, Tas., is a brown alga of the Ectocarpaceae.

Cladophora flavescens (Roth) Kützing 1845: 214; 1854: 5, pl. 22, fig. 1.

Recorded by Guiler (1952: 73) from Dover, Tas., on a Cribb specimen, which, however, came from a brackish creek. *C. flavescens* is regarded by Hauck (1885: 459) as a form of *C. glomerata* and inhabits fresh and brackish waters in Europe. It should not, therefore, be regarded as a marine form. Cribb's specimen does not agree well with Kützing's figure of *C. flavescens*.

Cladophora flexuosa (Griffiths) Harvey 1851: pl. 353.

Recorded by Guiler (1952: 73) from Port Arthur, Tas., on a Cribb specimen. This Tasmanian material does resemble *C. flexuosa* in general form but is considerably more slender than European specimens in AD. The branching is also somewhat different. While it is clearly allied to *C. flexuosa*, it is likely that it is not co-specific with it.

Cladophora fracta (Müller) Kützing 1843: 263.

Recorded by Tate (1882: 93) from "Holdfast Bay", S.A., also by Lucas (1912: 166). The specimen is in MEL and the label indicates that it came from stagnant pools with *Ruppia*, *Potamogeton*, etc., so apparently was growing in inland creeks. This species is normally restricted to freshwater habitats, and should be eliminated from marine records. May (1938: 214) records it from Stanwell Park, N.S.W., in a marine list.

Cladophora glomerata (Linnaeus) Kützing 1845: 212.

Recorded by Lucas (1912: 167) from Australia. This, however, is a freshwater species.

Cladophora gossypina Kützing 1849: 411.

Recorded by Sonder (1852: 658; from a ditch at Port Adelaide, S.A.) and by Harvey (1863: synop. 776). This is a freshwater species.

Cladophora insignis (Agardh) Kützing 1845: 217.

Recorded by Lucas (1912: 167) from Australia. This, however, is a freshwater species.

Cladophora subsimplex Kützing 1849: 411. (*C. simpliciuscula* Hooker 1847: 496, pl. 192, fig. 4.)

Recorded from St. Vincent's Gulf, S.A., by Tate (1882: 93). The type locality is Hermite I., Cape Horn, and the species is not likely to occur in Australia. The Australian specimen has not been located, but the type specimen of Kützing's *C. subsimplex* in L has been examined and I have seen nothing the same in Australian collections. For the time being it seems best to exclude this record.

Cladophora thoreana Kützing 1843: 268.

Recorded by Tate (1882: 93) from St. Vincent's Gulf, S.A. The specimens are in MEL but are in poor condition and scarcely identifiable. De Toni includes *C. thoreana* under *C. gracilis*, but the St. Vincent's Gulf specimens are not the latter, and do not agree very well with Kützing's description of *C. thoreana*. This record is best eliminated from the Australian algal flora.

Cladophora vaga Kützing 1849: 401.

Recorded by Tate (1882: 93) from Holdfast Bay. The specimen is in MEL. I have examined Kützing's type (in L) from St. Chamas, France, and do not consider the Holdfast Bay specimen to be the same.

Genus RHIZOCLONIUM Kützing

Rhizoclonium riparium (Roth) Harvey 1851: pl. 239. Cribb 1954: 17, pl. 1, fig. 9. De Toni 1889: 278. Kylin 1949: 50, fig. 51. Lucas 1936: 29, fig. 11. Newton 1931: 94, fig. 61. Setchell and Gardner 1920: 182. Smith 1944: 63, pl. 7, fig. 4. Taylor 1937: 83, pl. 1, fig. 3.

Conferva riparia Roth 1806: 216.

Type locality.—Northern Europe. *Type.*—Not in existence.

Distribution.—Almost cosmopolitan. In southern Australia it is known from Port Lincoln, Outer Harbour, and American River inlet on Kangaroo I., S.A., and from Port Arthur, Tas. (Cribb).

The Australian specimens agree well with the usual concept of *R. riparium*. Those from Outer Harbour, Port Lincoln, and Port Arthur show abundant rhizoids, but the American River inlet specimens lack rhizoids and might therefore be placed as var. *implexum*. The record of May (1938: 214) may belong to this latter taxon.

Two other species of *Rhizoclonium* occur in South Australia, but with the prevailing confusion in the genus it has not yet been possible to establish their affinities. Wilson (1892: 190) also recorded *Conferva arenosa* Carmichael (*Rhizoclonium arenosum* (Carm.) Kützing) but Wilson's specimen is not in MEL, and until it is found or the species is re-collected the record must remain as doubtful. One of the undetermined species mentioned above may prove to be the same as Wilson's.

Family **ANADYOMENACEAE**

Genus MICRODICTYON Decaisne

Microdictyon umbilicatum (Velley) Zanardini. Blackler 1949: 127. A. and E. S. Gepp 1906: 249. De Toni 1889: 361 (in part). Setchell 1929: 503, figs. 21–27; 1935: 130. May 1938: 213. Lucas 1912: 167. Womersley 1950: 144.

Conferva umbilicata Velley 1800: 169, pl. 7.

Microdictyon agardhianum Harvey 1858*a*: pl. 50; 1863; synop. 748. Kützing 1849: 512 (in part). Sonder 1852: 659; 1880: 39.

Microdictyon tenuis var. *australis* J. Agardh 1894: 106. [See Setchell 1929 for a full account of the synonymy.]

Type locality.—New South Wales (probably Port Jackson). *Type.*—LIV.

Distribution.—Stansbury, Yorke Peninsula, to Southport, Qld., in calm inlets and bays. Friendly Is.

Order **SIPHONALES**

Family **BRYOPSIDACEAE**

Genus BRYOPSIS Lamouroux

This is a notoriously difficult genus, and a thorough revision must depend on large numbers of liquid-preserved collections. Many dried specimens are almost useless, and the concept of species such as *B. australis* depends on definite material from near the type locality. At least two other apparently undescribed species occur, but available material is inadequate.

Bryopsis australis Sonder 1845: 49; 1846: 152. J. Agardh 1887: 26. De Toni 1889: 443. Harvey 1854: 565; 1863; synop. 741. Kützing 1849: 492; 1856: 28, pl. 81, fig. 1. Lucas 1912: 168. Sonder 1880: 38.

Type locality.—Western Australia (Preiss). *Type.*—MEL.

Distribution.—Only known for certain from the type collection, which is a poor specimen. Harvey's 569A from Fremantle (in MEL) is probably true *B. australis*.

It is very doubtful whether the records of Hylmo (1921: 15) from Feuerland and the Falkland Is., and of Taylor (1938: 135) from the Falkland Is., apply to true *B. australis*. A. and E. S. Gepp (1908: 170) consider that *B. australis* is distinguished by the ramuli arrangement of two double or triple rows of alternating ramuli. The type specimen, however, shows variation from this to ramuli scattered irregularly over the branches. A critical study of abundant liquid-preserved material from Western Australia to show the variation is needed for an elucidation of this species, and also to clarify the differences between *B. australis* and *B. indica*.

Bryopsis baculifera J. Agardh 1887: 21. De Toni 1889: 428. Lucas 1912: 168; 1913: 57, pl. 5, fig. 4. May 1938: 211. Wilson 1892: 187. Womersley 1950: 144.

Type locality.—Port Phillip Heads, Vic. (Wilson). *Type.*—LD (herb. Agardh No. 14898). Authentic material also in MEL.

Distribution.—Vivonne and Pennington Bays on Kangaroo I., S.A.; Port Phillip, Vic.; Tasmania (Rodway); Ryde, Parramatta River, N.S.W. (Lucas). This last record appears doubtful from Lucas's figure.

Bryopsis foliosa Sonder 1845: 49; 1846: 152; 1880: 38. J. Agardh 1887: 26. De Toni 1889: 432. Harvey 1863: synop. 742. Kützing 1849: 491. Lucas 1912: 168.

Bryopsis gracilis Sonder 1845: 49; 1846: 152; 1880: 38. J. Agardh 1887: 31. De Toni 1889: 438. Harvey 1863: synop. 743. Kützing 1849: 492. Lucas 1912: 168.

Type locality.—Western Australia (Preiss). *Type.*—MEL.

Distribution.—Only known for certain from the type collection. The types of *B. foliosa* and *B. gracilis* (both in MEL) are identical. Sonder (1846: 152) gives the same Preiss number for both species, so presumably they were the same collection. J. Agardh (1887: 26) recorded *B. foliosa* from Guadeloup I., but this record must be regarded as doubtful.

Bryopsis gemellipara J. Agardh 1887: 25. De Toni 1889: 432. Wilson 1892: 187.

Bryopsis hypnoides sensu Lucas 1912: 168; 1928: 9. Guiler 1952: 74.
Bryopsis australis sensu Guiler 1952: 74.

Type locality.—Queenscliff, Vic. (Wilson). *Type.*—LD (herb. Agardh No. 15150).

Distribution.—From Rottnest I. in Western Australia to Phillip I. in Victoria, and around Tasmania. This species appears most plentiful on moderately to very rough coasts at about low tide level, mainly in cooler Victorian and Tasmanian waters.

The ramuli vary from densely and irregularly arranged to sometimes distichous. The statement of A. and E. S. Gepp (1908: 170) that the ramuli are bifurcate at the base is incorrect. Some slender forms approach *B. australis*, but they are best kept separate until the latter is better understood. A collection of Cribb's (recorded by Guiler (1952: 74)) was previously incorrectly determined as *B. australis*.

Bryopsis indica A. & E. S. Gepp 1908: 169, pl. 22, figs. 10 and 11. Cribb 1954: 18, pl. 1, fig. 2.

Type locality.—Original localities are Coctivy, and Chagos Archipelago in the Indian Ocean (Gardiner). *Type.*—Probably in BM.

Distribution.—Indian Ocean; Queensland. In southern Australia, Kingscote, Kangaroo I. (possibly an isolated occurrence). This is typically a tropical species, not previously recorded from southern Australia.

The species is distinguished by the arrangement of the ramuli in two lots of alternating pairs, and the Australian specimens also usually have the older ramuli growing out into long rhizoidal structures. The relationships between this species and *B. australis* need clarifying.

Bryopsis minor Womersley 1955: 387, fig. 1.

Type locality.—American River inlet, Kangaroo I., S.A. (Womersley). *Type.*—AD (No. A4124).

Distribution.—Only known from the type locality.

Bryopsis pennata Lamouroux 1809*a*: 132, pl. 3, figs. 1*a* and 1*b*. J. Agardh 1887: 23. De Toni 1889: 430. Feldmann 1937: 221, fig. 24. Vickers 1908: 30, pl. 52.

Type locality.—West Indies. *Type.*—CN (herb. Lamouroux).

Distribution.—Widely distributed in warmer seas. A collection from Coffin's Bay, Eyre Peninsula, agrees very well with the type. This appears to be the first record from southern Australia.

Bryopsis plumosa (Hudson) C. Agardh 1821: 448. J. Agardh 1887: 24. De Toni 1889: 431. Guiler 1952: 74. Harvey 1851: pl. 3; 1863: synop. 740. Koster 1941: 242, fig. 2 (2–7). Kylin 1949: 66, fig. 64. Lucas 1912: 168; 1928: 9; 1936: 33. May 1938: 211. Newton 1931: 97, fig. 64. Reinbold 1897: 44; 1899: 40. Setchell and Gardner 1920: 161, pl. 14, figs. 1 and 2. Sonder 1853: 507; 1880: 38. Wilson 1892: 187. Womersley 1950: 144.

Type locality.—Exmouth, England. *Type.*—Apparently lost.

Distribution.—Almost cosmopolitan, and recorded from numerous localities along southern Australia.

This is apparently a fairly variable species. While some Australian specimens agree well with European material, having strictly distichous ramuli, others are more doubtful, with ramuli sometimes distichous but often occurring on all sides.

SPECIES OF BRYOPSIS INCORRECTLY RECORDED FROM SOUTHERN AUSTRALIA

Bryopsis cupressoides Lamouroux 1809*a*: 135, pl. 1, fig. 3.

This species was recorded by Womersley (1950: 144). A study of the type of *B. cupressina* (as the name was originally spelt) shows that the Kangaroo I. plant is quite distinct, probably belonging to an undescribed species. True *B. cupressina* is not known from Australia.

Bryopsis hypnoides Lamouroux 1809*a*: 135, pl. 1, fig. 2.

The records of Lucas (1912: 168; 1928: 9) and Guiler (1952: 74) apply to a Rodway specimen from Eaglehawk Neck, Tas., which proves on examination to be *B. gemellipara* J. Agardh. True *B. hypnoides* (type in CN (herb. Lamouroux)) does not seem to occur in Australia, though there are at least two closely related species.

Bryopsis vestita J. Agardh 1887: 30.

This is a New Zealand species (type locality, Chatham I.) recorded from Australia by Reinbold (1898: 34) on the basis of a juvenile plant. This specimen has not been located, but in the absence of any other collection of true *B. vestita* from the Lacépède Bay region of Reinbold's record, I am not prepared to accept the record. Very likely Reinbold's specimen was *B. gemellipara*, which is common in that region.

Family CAULERPACEAE

Genus CAULERPA Lamouroux

Caulerpa alternans nom. nov.

Caulerpa alternifolia J. Agardh 1887: 129. De Toni 1889: 449. Lucas 1912: 169; 1931*a*: 87. Weber van Bosse 1898: 298, pl. 15, fig. 1. Wilson 1892: 188.

Type locality.—Port Phillip Heads, Vic. (Wilson). *Lectotype.*—LD (herb. Agardh No. 16416). Isotype in MEL.

Distribution.—Only known from St. Vincent's Gulf, S.A. ("dredged in 20 fathoms"), and Port Phillip Heads, Vic.

The renaming of this species is necessary owing to the earlier *Caulerpa alternifolia* Crouan and Crouan (1865: 41), which is given by Weber van Bosse as a synonym of *C. cupressoides*.

Caulerpa annulata Lucas 1931*b*: 410, pl. 27, fig. 1. Guiler 1952: 74.

Caulerpa cactoides sensu Guiler 1952: 74 (in part, as to Actaeon I. specimen).

Type locality.—Port Arthur, Tas. (Lucas). *Type.*—CANB (herb. Lucas, temporarily at NSW). Isotype in AD.

Distribution.—Only known from Port Arthur and Actaeon I., Tas., Portland, Vic., and Ardrossan, S.A.

This is apparently a rare species, closely related to but distinct from *C. articulata* (*C. hodkinsoniae*) from New South Wales and New Zealand.

Caulerpa brownii (C. Agardh) Endlicher 1843: 16. J. Agardh 1872: 28. De Toni 1889: 468. Guiler 1952: 74. Harvey 1855*b*: 260, pl. 121*A*; 1860*b*: 337; 1863: synop. 723. Hooker and Harvey 1847: 416. Levring 1945: 7. Lucas 1912: 169; 1928: 10; 1931*a*: 89, fig. 1; 1935: 199; 1936: 42, figs. 23 and 24. Reinbold 1898: 35; 1899: 41. Sonder 1880: 37 (not 1852: 661 = *C. longifolia*). Weber van Bosse 1898: 306, pl. 25, fig. 3. Womersley 1950: 146.

Caulerpa selago var. *brownii* C. Agardh 1821: 442; 1824: 183.
Caulerpa selago sensu Sonder 1852: 661; 1853: 507.
Chauvinia brownii Trevisan 1849: 138.
Chauvinia selago var. *brownii* Kützing 1849: 497.
Caulerpa furcifolia Hooker and Harvey 1847: 416. Harvey 1854: 564; 1855*b*: 260, pl. 221*B*; 1860*b*: 337; 1863: synop. 724.
Chauvinia furcifolia Kützing 1849: 497; 1857: 5, pl. 11, 2. Trevisan 1849: 139.

Type locality.—Kent I., Bass Strait (R. Brown). *Type.*—LD (herb. Agardh, No. 16647).

Distribution.—From Cape Leeuwin, W.A., to Walkerville, Vic., and around Tasmania. New Zealand; Chatham I.; Stewart I.; Lord Howe I. (?)

Two varieties (var. *minor* and var. *selaginoides*) were described by J. Agardh, and also recognized by Weber van Bosse. Var. *minor* includes slender plants, var. *selaginoides* larger, more robust ones. The differences are probably due to ecological factors as all grades between the varieties occur. The New Zealand forms, however, all fall within var. *selaginoides*.

Caulerpa cactoides (Turner) C. Agardh 1821: 439; 1824: 182. J. Agardh 1872: 44. De Toni 1889: 485; 1896: 231. Endlicher 1843: 16. Guiler 1952: 74. Greville 1830: lxiii. Harvey 1858*a*: pl. 26; 1860*b*: 338; 1863: synop. 718. Levring 1946: 216. Lucas 1912: 170; 1928: 10; 1931*a*: 93, fig. 6; 1936: 48. May 1938: 213. Murray 1891: 211, pl. 52, figs. 6 and 8. Reinbold 1897: 44; 1899: 41. Sonder 1852: 661; 1853: 507; 1880: 37. Weber van Bosse 1898: 390. Womersley 1950: 146.

Fucus cactoides Turner 1811: 90, pl. 171.
Ahnfeldtia cactoides Trevisan 1849: 142.
Chauvinia cactoides Kützing 1849: 499; 1857: 6, pl. 15, fig. 4.
Tricladia australis Decaisne 1842: 337; 1864: 6, pl. 1, fig. 2. Endlicher 1843: 17. Kützing 1849: 494. Trevisan 1849: 144.
Caulerpa corynephora sensu Harvey 1854: 564 (non Montagne).

Type locality.—"Southern coast of Australia" (R. Brown). *Type.*—BM.

Distribution.—From Port Denison, W.A., around southern Australia to the Richmond River, N.S.W. (possibly to Cape Upstart in Queensland), and around Tasmania.

Caulerpa corynephora Montagne (1842: 14) was described from a specimen collected by D'Urville at Toud I. in Torres Strait. This specimen, now in the Paris Museum, is similar to a slender *C. cactoides*. Harvey considered Montagne's species identical with *C. cactoides*, but Weber van Bosse (1898: 364) classes it as a variety of *C. racemosa*. A specimen in herb. Harvey (TCD) named *C. corynephora* var. *minus*, from Tasmania (C. Stuart), is probably *C. annulata* Lucas.

Murray (1891: 211, pl. 52, fig. 8) described var. *gracilis* of *C. cactoides*, but this does not seem to warrant varietal rank.

Caulerpa cliftoni Harvey 1863: synop. 728. De Toni 1889: 487. Lucas 1912: 169; 1931*a*: 89; 1931*b*: 411, pl. 25, fig. 2; 1936: 41, fig. 22. Reinbold 1899: 41. Sonder 1880: 37. Weber van Bosse 1898: 303.

Caulerpa abies-marina J. Agardh 1872: 18. De Toni 1889: 456. Lucas 1912: 169. Sonder 1880: 37. Wilson 1892: 188.

Type locality.—Western Australia (Clifton). *Type.*—TCD.

Distribution.—Western Australia (probably Fremantle) to Port Phillip Heads, Vic. A comparatively rare species.

Caulerpa distichophylla Sonder 1845: 50; 1846: 150; 1880: 37. J. Agardh 1872: 25. De Toni 1889: 464. Harvey 1860*a*: pl. 161; 1863: synop. 717. Kützing 1849: 496; 1857: 4, pl. 8, fig. 2. Weber van Bosse 1898: 341, pl. 31, fig. 1.

Caulerpa tenella Harvey 1854: 564.
Corradoria distichophylla Trevisan 1849: 134.

Type locality.—Western Australia (Preiss). *Type.*—MEL.

Distribution.—Rottnest I. and near Fremantle, W.A.; Kangaroo I.; Bridgewater Bay, Vic. This is apparently a rare species, except possibly in Western Australia where it occurs in rock pools on reefs.

Caulerpa ellistoniae Womersley 1955: 387, fig. 2.

Type locality.—Elliston, S.A. (Womersley). *Type.*—AD (No. A13426).

Distribution.—Only known from the type locality.

Caulerpa flexilis Lamouroux 1813: 283, pl. 13, fig. 3. C. Agardh 1821: 443; 1824: 183. J. Agardh 1872: 29. De Toni 1889: 469. Endlicher 1843: 16. Greville 1830: lxiv. Guiler 1952: 74. Lucas 1912: 169; 1928: 10. Reinbold 1898: 35. Sonder 1880: 37. Tate 1882: 93.

Chauvinia flexilis Kützing 1849: 497; 1857: 7, pl. 18, fig. 2. Trevisan 1849: 139.
Fucus hypnoides R. Brown in Turner 1811: 94, pl. 173.
Caulerpa hypnoides C. Agardh 1821: 443; 1824: 183. J. Agardh 1872: 30. De Toni 1889: 470; 1896: 231. Endlicher 1843: 16. Greville 1830: lxiv. Guiler 1952: 74. Harvey 1854: 564; 1855*b*: 260; 1859: pl. 84; 1860*b*: 337; 1863: synop. 725. Hooker and Harvey 1847: 416. Lucas 1912: 169; 1928: 10; 1931*a*: 91; 1936: 44, fig. 27. May 1938: 212. Reinbold 1898: 35. Sonder 1846: 150; 1852: 662; 1880: 37. Tepper 1883: 66. Weber van Bosse 1898: 342, pl. 29. Wilson 1892: 188. Womersley 1950: 146.
Chauvinia hypnoides Kützing 1849: 497; 1857: 7, pl. 18, 1. Trevisan 1849: 138.
Caulerpa turneri Lamouroux 1823: 282.

Type locality.—Esperance, W.A. (see C. Agardh 1821: 443). *Type.*—CN.

Distribution.—Champion Bay, W.A., around southern Australia to about Sydney in New South Wales, and around Tasmania. New Zealand (North Island).

var. **muelleri** (Sonder) comb. nov.

Caulerpa muelleri Sonder 1852: 661; 1880: 37. J. Agardh 1872: 31. De Toni 1889: 470. Harvey 1854: 564; 1858*a*: pl. 2; 1863: synop. 726. Lucas 1912: 169; 1928: 10; 1931*a*: 91; 1936: 46, fig. 28. May 1938: 212. Wilson 1892: 189.

Caulerpa hypnoides var. *muelleri* (Sonder) Weber van Bosse 1898: 349, pl. 29, figs. 5 and 6. Guiler 1952: 74. Womersley 1950: 146.

Type locality.—Rivoli Bay, S.A. (F. v. Mueller). *Type.*—MEL.

Distribution.—Rottnest I., W.A., around southern Australia to New South Wales, and the north coast (at least) of Tasmania.

Unfortunately the well-known *C. hypnoides* R. Brown is invalidated by *C. hypnoides* Lamouroux (1809*b*; 141) which is considered (Weber van Bosse 1898: 323) as a synonym of *C. cupressoides*. The earliest available name is *C. flexilis* Lamouroux, described in 1813 only by means of a figure. This figure, however, is recognizable as the upper part of a loosely branched plant, and agrees well with the type specimen in herb. Lamouroux, Caen. Although no description was given by Lamouroux, his recognizable figure validates the name under Art. 44 (3) of the International Rules of Botanical Nomenclature.

This species is very variable, depending on its habitat. Weber van Bosse recognized four varieties, as well as several forms, of *C. hypnoides*: viz. var. *flexilis*, var. *laxa*, var. *typica*, and var. *muelleri*. Of these, var. *muelleri*, with denser and more crowded ramenta, is probably the only one worth recognizing.

Caulerpa hedleyi Weber van Bosse 1910: 1, pl. 1, figs. 1–4. Lucas 1912: 169; 1927: 559; 1936: 43, fig. 25. Womersley 1950: 146.

Type locality.—"Off Kangaroo Island" (dredged in 8 fathoms) (Hedley). *Type.*—NSW.

Distribution.—Only known from the original collection, although intensive collecting around Kangaroo I. has occurred in recent years.

Caulerpa longifolia C. Agardh 1821: 437; 1824: 181. J. Agardh 1872: 16. De Toni 1889: 455. Endlicher 1843: 16. Greville 1830: lxiii. Guiler 1952: 74. Kützing 1849: 496. Lucas 1912: 169; 1931*a*: 88; 1936: 38, fig. 18. Sonder 1880: 37. Womersley 1950: 146.

Corradoria longifolia Trevisan 1849: 134.

Caulerpa harveyi F. von Mueller in Harvey 1859: pl. 95; 1860*b*: 338; 1863: synop. 729. J. Agardh 1872: 17. De Toni 1889: 455. Lucas 1912: 169; 1928: 10; 1931*a*: 88; 1936: 41, fig. 21. Reinbold 1898: 35. Sonder 1880: 37. Weber van Bosse 1898: 299. Wilson 1892: 188.

Caulerpa brownii Sonder 1852: 661 (non Endlicher).

Chauvinia brownii Kützing 1857: 5, pl. 12, fig. 1.

Type locality.—Southern Australia. *Type.*—PC.

Distribution.—Elliston in South Australia to Wilson's Promontory in Victoria and around Tasmania.

forma **crispata** (Harvey) Womersley 1950: 147. Guiler 1952: 74.

Caulerpa harveyi var. *crispata* Harvey 1859: pl. 95 (var. β); 1860*b*: 338. Weber van Bosse 1898: 300.

Caulerpa curvifolia J. Agardh in Wilson 1892: 188 (nomen nudum).

Type locality.—Port Phillip Heads, Vic. (Harvey). *Type*.—TCD.

Distribution.—Garden I., W.A., to Western Port, Vic., and around Tasmania.

An account of this species has been given previously (Womersley 1950: 147). The type sheet of *C. longifolia* bears one good specimen which is intermediate between the form known as *C. harveyi* and Harvey's var. *crispata*, but closer to the former. It seems best to reduce *crispata* to a form only, as the variation from one extreme to the other is continuous, and plants have been seen with young parts of the *crispata* form and older parts typical *C. longifolia* (*C. harveyi*). However, the extreme forms are usually so distinctive that they can usefully bear distinguishing names.

Caulerpa obscura Sonder 1845: 50; 1846: 150; 1853: 507. Guiler 1952: 74. Harvey 1854: 564; 1860*b*: 337. Lucas 1931*a*: 89; 1936: 38, fig. 19. Reinbold 1899: 41. Weber van Bosse 1898: 301. Womersley 1950: 147.

Chauvinia obscura Kützing 1849: 497; 1857: 7, pl. 17, fig. 2. Trevisan 1849: 139.

Caulerpa sonderi F. v. Mueller in Sonder 1852: 661; 1853: 507; 1880: 37. J. Agardh 1872: 18. De Toni 1889: 456. Harvey 1860*a*: pl. 167; 1863: synop. 727. Kützing 1857: 4, pl. 7. Lucas 1912: 169; 1928: 10. Reinbold 1897: 45. Wilson 1892: 189.

Caulerpa superba Greville 1854: 197, pl. 10.

Caulerpa abies Areschoug 1854: 366. De Toni 1889: 471. Lucas 1912: 169; 1931*a*: 92.

Type locality.—Western Australia (Preiss). *Type*.—Not located in MEL.

Distribution.—Cottesloe in Western Australia to Western Port in Victoria, and around Tasmania.

Although the type of *C. obscura* has not been located in MEL, where it should be, there seems no doubt from Sonder's description that it is identical with his *C. sonderi*, the type of which is in MEL. The type of Greville's *C. superba* also could not be found at E, but his figure leaves no doubt concerning the name. Weber van Bosse recognized two forms, *typica* and *sonderi*, which are apparently only growth forms.

Caulerpa papillosa J. Agardh 1872: 42. De Toni 1889: 483. Lucas 1912: 170; 1931*a*: 93; 1936: 48. May 1951: 93. Sonder 1880: 37. Weber van Bosse 1898: 383, pl. 34, fig. 8. Wilson 1892: 189.

Type locality.—Queenscliff, Vic. (F. v. Mueller). *Type*.—LD (herb. Agardh No. 16849).

Distribution.—From Venus Bay, Eyre Peninsula, to Phillip I., Vic., and near the mouth of the Currie River, Tas. Also recorded from Brampton I., Qld., by May.

Caulerpa racemosa (Forskål) J. Agardh var. **laetevirens** (Montagne) Weber van Bosse forma **cylindracea** (Sonder) Weber van Bosse 1898: 366, pl. 33, figs. 17, 19, and 20.

Caulerpa cylindracea Sonder 1845: 50; 1846: 151; 1880: 37. J. Agardh 1872: 34. De Toni 1889: 474. Harvey 1854: 564; 1858*a*: pl. 30; 1863: synop. 719. Lucas 1912: 169.

Chauvinia cylindracea Kützing 1849: 498; 1857: 6, pl. 15, fig. 2.

Ahnfeldtia cylindracea Trevisan 1849: 144.

Caulerpa laetevirens Harvey 1854: 563.

Type locality (of f. *cylindracea*).—Western Australia (Preiss). *Type*.—MEL.

Distribution.—Tropical Australia, reaching as far south as King George's Sound, W.A. (in a rather depauperate form), but common and well developed on Rottnest I. and near Perth.

It is doubtful whether it is worth recognizing *cylindracea* as a distinct form of var. *laetevirens* of the highly variable *C. racemosa*.

Caulerpa remotifolia Sonder 1852: 660; 1880: 37. J. Agardh 1872: 12. De Toni 1889: 448. Harvey 1859: pl. 107; 1863: synop. 715. Kützing 1857: 4, pl. 9. Lucas 1912: 169. Weber van Bosse 1898: 286. Womersley 1950: 147.

Type locality.—Lefebre Peninsula, S.A. (F. v. Mueller). *Type*.—MEL.

Distribution.—In South Australia, known from Lefebre Peninsula and sheltered bays on the north coast of Kangaroo I. In Victoria, from Port Phillip Bay (mouth of Little River, J. H. Willis). Kützing (1857: 4) gives "Tasmania. F. Mueller (herb. Sonder)", but there are no Tasmanian specimens from herb. Sonder in MEL, and the locality is probably an error. Sonder (1880: 37) also gives "West Australia".

Caulerpa scalpelliformis (R. Brown in Turner) C. Agardh 1821: 437; 1824: 181. J. Agardh 1872: 12. De Toni 1889: 449. Endlicher 1843: 16. Greville 1830: lxiii. Guiler 1952: 74. Harvey 1854: 564; 1858*a*: pl. 17; 1860*b*: 338; 1863: synop. 714. Kützing 1849: 496; 1857: 3, pl. 6, fig. 1. Lucas 1912: 169; 1928: 10; 1931*a*: 87, fig. 5; 1936: 34, fig. 16. May 1938: 212. Reinbold 1898: 35. Sonder 1846: 149; 1880: 37. Weber van Bosse 1898: 286, pl. 22, fig. 11, pl. 23, figs. 1–4. Wilson 1892: 189. Womersley 1950: 147.

Fucus scalpelliformis R. Brown in Turner 1811: 96, pl. 174.
Corradoria scalpelliformis Trevisan 1849: 133.

Type locality.—South coast of Australia (R. Brown). *Type*.—BM.

Distribution.—From Rottnest I. in Western Australia around southern Australia to Jervis Bay in New South Wales and around Tasmania. Var. *denticulata* (Decaisne) W. v. Bosse and var. *intermedia* W. v. Bosse are known from the East Indies, Ceylon, and the Red Sea.

Whether var. *intermedia* is worth recognizing is doubtful. This species in southern Australia is a distinct one, but very variable in width and robustness of thallus.

Caulerpa sedoides (R. Brown in Turner) C. Agardh 1821: 438; 1824: 182. J. Agardh 1872: 39. De Toni 1889: 480. Endlicher 1843: 16. Greville 1830: lxiii. Guiler 1952: 74. Harvey 1855*b*: 261; 1859: pl. 72; 1860*b*: 338; 1863: synop. 720. Hooker and Harvey 1847: 416. Lucas 1912: 170; 1927: 556; 1928: 10; 1931*a*: 12, fig. 3; 1936: 47. May 1938: 213. Montagne 1845: 13. Sonder 1846: 150; 1852: 660; 1853: 507; 1880: 37. Weber van Bosse 1898: 387, pl. 34, figs. 10 and 11; 1910: 8. Wilson 1892: 189. Womersley 1950: 148.

Fucus sedoides R. Brown in Turner 1811: 92, pl. 172.
Chauvinia sedoides Kützing 1849: 498; 1857: 6, pl. 15, fig. 1.
Ahnfeldtia sedoides Trevisan 1849: 143.
Caulerpa geminata Harvey 1854: 564.

Type locality.—Kent I., Bass Strait (R. Brown). *Type*.—BM.

Distribution.—From Rottnest I. in Western Australia around southern Australia to Bowen, Qld., and around Tasmania. New Zealand; Friendly Is.

Weber van Bosse recognizes three forms, f. *tasmanica* J. Agardh, f. *geminata* Harvey, and f. *crassicaulis* J. Agardh. These appear to be only growth or ecological forms, the arrangements and size of the ramenta being very variable, even on one plant.

Caulerpa simpliciuscula (Turner) C. Agardh 1821: 439; 1824: 182. J. Agardh 1872: 41. De Toni 1889: 482. Endlicher 1843: 16. Guiler 1952: 74. Harvey 1854: 563; 1859: pl. 65 in part (not figs. 3 and 4 = *C. vesiculifera*); 1860*b*: 338; 1863: synop. 722. Lucas 1912: 170; 1928: 10; 1931*a*: 93, fig. 4; 1936: 47. Sonder 1853: 507; 1880: 37. Weber van Bosse 1898: 377, pl. 34, figs. 3 and 4. Wilson 1892: 189. Womersley 1950: 148.

Fucus simpliciusculus Turner 1811: 98, pl. 175.
Codium simpliciusculum Greville 1830: lxvii.
Ahnfeldtia simpliciuscula Trevisan 1849: 143.
Chauvinia simpliciuscula Kützing 1849: 499; 1857: 5, pl. 11, fig. 3.
Caulerpa vesiculifera J. Agardh 1872: 40 in part.

Type locality.—Kent I., Bass Strait (R. Brown). *Type.*—BM.

Distribution.—Port Denison, W.A., around southern Australia to Wilson's Promontory, Vic., and around Tasmania.

var. **laxa** nom. nov.

C. simpliciuscula var. *vesiculifera* Harvey in original MS. sense. Weber van Bosse 1898: 378. Guiler 1952: 74. Womersley 1950: 148. *Not* Harvey 1859: pl. 65, figs. 3 and 4 (= *C. vesiculifera* Harvey).

Type locality.—Georgetown, Tas. (Gunn?). *Type.*—TCD.

Distribution.—North coast of Kangaroo I., S.A., to Phillip I., Vic., and around Tasmania. This variety occurs in calm, sheltered waters, whereas the species occurs on more open, rougher coasts.

The ramenta are only slightly larger than those in the species (500–700 μ broad against 300–600 μ broad) but are more loosely arranged, thinner-walled, and collapse on drying. Possibly var. *laxa* may prove to be an ecological form of the species, but in the absence of good evidence for this it is best kept as a distinct variety.

Much confusion has existed between *C. simpliciuscula* var. *laxa* and *C. vesiculifera* Harvey (= *C. ethelae* Weber van Bosse). Harvey's earliest specimen of his var. *vesiculifera* of *C. simpliciuscula* was one from Georgetown, Tas., dated "June 1849". This is in TCD and represents Harvey's earliest concept of his variety, which, however, was not described until 1859. By this time Harvey had distributed and placed in his herbarium another entity as var. *vesiculifera*, and his 1859 description applies clearly to this latter alga. He described the ramenta as being very much larger than in the species, more loosely arranged and swollen, and of a darker green colour. Together with his figures (1859: pl. 65, figs. 3 and 4), this clearly indicates the entity he was describing, and this he later (1863: synop. 721) raised to specific rank as *C. vesiculifera*.

Weber van Bosse (1898: 379) comments on two discrepancies in Harvey's account. Firstly, Harvey (1859) described the variety as "more slender" than the species, whereas it is usually just as robust; secondly, his Figure 4 in Plate 65 shows a vesicle without the papillate base which Weber van Bosse showed to be a feature of the entity.

There are, as far as is known, only two taxa involved, and it is clear that Harvey's *C. vesiculifera* and Weber van Bosse's *C. ethelae* are the same entity. Harvey's "more-slender" description does not invalidate the rest of his quite unmistakable description, and his failure to show the papillate base of the ramenta is not surprising in dried material at that time.

Harvey's 1863 description of the species *C. vesiculifera* was validated by his reference to his previous figures and description as var. *vesiculifera*, and his specimens from the first two localities given (Western Port and Port Phillip) are *C. vesiculifera;* his specimens from his third locality (Georgetown), were mostly var. *laxa* of *C. simpliciuscula*, but may have included *C. vesiculifera*.

C. vesiculifera Harvey, 1863, thus appears to be a validly described species, and Weber van Bosse had insufficient grounds for renaming it *C. ethelae*. As *C. simpliciuscula* var. *vesiculifera* of Weber van Bosse was not the same as Harvey's described variety (though the same as Harvey's original herbarium use of the name), this entity is renamed var. *laxa*.

Caulerpa trifaria Harvey 1863: pl. 261, synop. 730. J. Agardh 1872: 16. De Toni 1889: 454. Guiler 1952: 75. Lucas 1912: 169; 1928: 10; 1931*a*: 88; 1936: 39, fig. 20. Sonder 1880: 37. Weber van Bosse 1898: 229. Wilson 1892: 189. Womersley 1950: 148.

Caulerpa plumaris var. *elegans* Reinbold 1897: 44.
Caulerpa sertularioides sensu Lucas 1936: 34.

Type locality.—Port Phillip Heads (Harvey). *Type.*—TCD.

Distribution.—From Cottesloe, W.A., to Western Port in Victoria and around Tasmania. A plant of relatively calm coasts.

Caulerpa vesiculifera Harvey 1863: synop. 721. J. Agardh 1872: 40. De Toni 1889: 481. Lucas 1912: 170; 1928: 10; 1931*a*: 92; 1936: 47. Reinbold 1898: 35. Sonder 1880: 37. Wilson 1892: 189.

Caulerpa simpliciuscula var. *vesiculifera* Harvey 1859: pl. 65, figs. 3 and 4 (not figs. 1 and 2).
Caulerpa ethelae Weber van Bosse 1898: 384, pl. 34, figs. 5 and 6. Womersley 1950: 146.

Type locality.—Western Port, Vic. (Harvey). *Type.*—TCD.

Distribution.—From Elliston in South Australia to Western Port, Vic., and probably on the north coast of Tasmania. This species is discussed under *Caulerpa simpliciuscula* var. *laxa*.

Family DERBESIACEAE

Genus DERBESIA Solier

Derbesia clavaeformis (J. Agardh) De Toni 1889: 425. Lucas 1912: 168. Womersley 1950: 144.

Bryopsis clavaeformis J. Agardh 1887: 20. Lucas 1912: 168. Wilson 1892: 187.

Type locality.—Western Port, Vic. (Wilson). *Type.*—LD (herb. Agardh No. 14897).

Distribution.—Only known from Port Phillip and Western Port, Vic., and West Bay and Pennington Bay on Kangaroo I.

Derbesia marina (Lyngbye) Solier. Kjellmann 1897: 1–21, pl. 1. Borgesen 1903: 520. De Toni 1889: 426. Kylin 1949: 68. Setchell and Gardner 1920: 165, pl. 15, fig. 3. Smith 1944: 71, pl. 8, fig. 4.

Vaucheria marina Lyngbye 1819: 79, pl. 22A.

Type locality.—Faroe Is. *Type.*—C (herb. Lyngbye).

Distribution.—Northern Europe; Pacific coast of North America. In Australia, from Scott's Bay, Eyre Peninsula, and Vivonne Bay, Kangaroo I.

The South Australian material agrees in all respects with liquid-preserved and dried specimens of Borgesen's from the Faroes (seen in C), and is very like Lyngbye's figures. Lyngbye's type specimen is scarcely suitable for examination.

Family CODIACEAE

Genus AVRAINVILLEA Decaisne

Avrainvillea clavatiramea A. & E. S. Gepp 1911: 33, figs. 92 and 93. Lucas 1912: 170.

Avrainvillea obscura Wilson 1892: 188.

Type locality.—Corio Bay, Port Phillip, Vic. (Wilson). *Type.*—BM.

Distribution.—Only known from the type locality.

This is the only species of this tropical genus known from southern Australia, and is apparently rare.

Genus CALLIPSYGMA J. G. Agardh

Callipsygma wilsonis J. Agardh 1887: 65–7. De Toni 1889: 505. A. and E. S. Gepp 1904: 364, pl. 467, figs. 5–7; 1911: 63, figs. 144–146. Lucas 1912: 170. Printz 1927: 317, fig. 247. Wille 1897: 142; 1911: 128. Wilson 1892: 188.

Type locality.—Sorrento, Port Phillip Heads, Vic. (Wilson). *Type.*—LD (herb. Agardh No. 15723). Type fragment in BM.

Distribution.—Only the type collection known.

Genus CHLORODESMIS Bailey & Harvey

Chlorodesmis australis Womersley 1955: 388, fig. 3.

Type locality.—Robe, S.A. (Womersley). *Type.*—AD (No. 12250).

Distribution.—Type locality and Pennington Bay, Kangaroo I.

Chlorodesmis pusilla Womersley 1955: 389, fig. 4.

Type locality.—Pennington Bay, Kangaroo I., S.A. (Womersley). *Type.*—AD (No. A7020).

Distribution.—Type locality and Vivonne Bay, Kangaroo I.

Genus CODIUM Stackhouse

A full taxonomic account of *Codium* in southern Australia is given by Silva and Womersley (1956).

Codium australicum Silva in Silva and Womersley 1956.

Type locality.—Robe, S.A. (Wollaston). *Type.*—AD (No. 20409).

Distribution.—Geographe Bay, W.A., around southern Australia to Maroubra Bay, N.S.W.; Tasmania. New Zealand.

Codium capitulatum Silva & Womersley 1956.

Type locality.—Elliston, S.A. (Womersley). *Type.*—AD (No. A19384).

Distribution.—From Point Sinclair to Point Westall, on the west coast of Eyre Peninsula and Port Willunga in St. Vincent's Gulf, S.A. Point Lonsdale, Vic. (Iona Maclennan, UC).

Codium dimorphum Svedelius 1900: 300, pl. 16, fig. 1; pl. 17, figs. 16–19.

Codium adhaerens var. *incrassatum* Dellow 1952: 124, figs. 8 and 9.

Type locality.—Melinca, Guaitecas Is., Chili (P. Dusen). *Type.*—Herb. Svedelius, Uppsala; fragment in UC.

Distribution.—East coast of Tasmania (Port Arthur, Tasman I., and Cape Forestier). New Zealand; Chatham I.; Chile.

Codium duthiae Silva in Silva and Womersley 1956.

Codium elongatum Harvey 1863: synop. 734. Lucas 1912: 171 in part. Sonder 1880: 38 in part. Wilson 1892: 187.

Codium decorticatum Lucas 1936: 56 (in part). Guiler 1952: 75?

Codium galeatum Womersley 1950: 145 (in part).

Type locality.—Strandfontein, False Bay, South Africa (G. F. Papenfuss, Nov. 13, 1935). *Type.*—UC (No. 920260).

Distribution.—From Champion Bay, W.A., to Western Port in Victoria. South Africa. In Australia *C. duthiae* is mainly found in quiet sheltered bays and inlets, such as St. Vincent's and Spencer Gulfs, and American River inlet on Kangaroo I.

Codium fragile (Suringar) Hariot. De Toni 1889: 495. Guiler 1952: 75. Levring 1946: 216. Lucas 1936: 54, fig. 37. May 1938: 212. Schmidt 1923: 47, figs. 29–32. Setchell and Gardner 1920: 171, pl. 28 and 29. Silva 1951: 96, fig. 22.

Acanthocodium fragile Suringar 1867: 258.

Codium tomentosum sensu Guiler 1952: 75 (in part). Harvey 1860*b*: 339; 1863: synop. 733 (in part). Hooker and Harvey 1847: 416. Sonder 1853: 506; 1880: 38 (in part).

Codium tomentosum var. *australasicum* Areschoug 1854: 368 (in part).

Codium mucronatum J. Agardh 1887: 43. Cotton 1912: 115, pl. 8, fig. 7. De Toni 1889: 494. Lucas 1912: 171; 1928: 10. Wilson 1892: 187.

Type locality.—Japan (Textor). *Type.*—L (No. 910.187–1712).

Distribution.—From Victor Harbour, S.A., around Victoria to Brisbane in Queensland (possibly to Rockingham Bay) and around Tasmania. The Australian form was separated by J. Agardh (1887: 44) as var. *tasmanicum*. Var. *novae-zelandiae* also occurs in south-eastern Australia (see Silva and Womersley 1956).

Codium galeatum J. Agardh 1887: 42, pl. 1, fig. 1. De Toni 1889: 494. Guiler 1952: 75. Lucas 1912: 171; 1913: 59; 1928: 10; 1936: 54, fig. 35*a*. Schmidt 1923: 45, fig. 27. Wilson 1892: 187. Womersley 1950: 145 (in part).

Codium tomentosum sensu Harvey 1854: 564; 1863: synop. 733 (in part). Sonder 1852: 660 (as to Rivoli Bay locality); 1880: 38.

Codium tomentosum var. *australasicum* Areschoug 1854: 368 (in part).

Type locality.—Port Phillip, Vic. (F. v. Mueller). *Lectotype.*—LD (herb. Agardh No. 15588).

Distribution.—From Champion Bay, W.A., around southern Australia to Ballina, N.S.W. (possibly to Rockingham Bay in Queensland), and around Tasmania.

In the original description J. Agardh gave as a synonym (in part) *Fucus simpliciusculus* Turner (= *Caulerpa simpliciuscula*). This is incorrect as there is no *Codium* on Turner's type sheet of this species.

Codium harveyi Silva in Silva and Womersley 1956.

Type locality.—Vivonne Bay, Kangaroo I., S.A. (Womersley). *Type.*—AD (No. 10557).

Distribution.—Champion Bay, W.A., along southern Australia to Lake Macquarie, N.S.W.; Tasmania. New Zealand.

Codium laminarioides Harvey 1854: 565; 1863: synop. 735. J. Agardh 1887: 47. De Toni 1889: 497. Lucas 1912: 171. Schmidt 1923: 59. Sonder 1880: 38.

Type locality.—Rottnest I., W.A. (Harvey). *Lectotype.*—TCD (Harvey No. 574).

Distribution.—Cottesloe to King George's Sound, W.A.

Codium lucasii Setchell in Lucas 1935: 200, fig. 3; 1936: 50, figs. 31*a-h*. Guiler 1952: 75. May 1938: 212. Silva 1951: 87, 92–4, fig. 11. Womersley 1950: 145.

Codium adhaerens sensu Harvey 1863: synop. 739. Lucas 1912: 171. May 1938: 212. Sonder 1880: 38.

Type locality.—Bondi, N.S.W. (Lucas). *Type.*—UC (395199).

Distribution.—From Cottesloe, W.A., around southern Australia, to Redcliffe, Qld., and around Tasmania. Lord Howe I.

Codium mamillosum Harvey 1854: 565; 1858*a*: pl. 41; 1863: synop. 737. J. Agardh 1887: 39. De Toni 1889: 491. Lucas 1912: 171; 1927: 558; 1929: 46; 1936: 53, fig. 34. Schmidt 1923: 37, fig. 17. Sonder 1880: 38. Womersley 1950: 145; 1953: 36.

Codium bursa var. *australis* Sonder 1852: 660; 1853: 506.

Codium bursa sensu Sonder 1880: 38. Guiler 1952: 75? Harvey 1863: synop. 738. Lucas 1912: 171; 1928: 10. Wilson 1892: 187. (These references apply mainly to *C. mamillosum* but many probably also apply to *C. pomoides.*)

Type locality.—Fremantle, W.A. (Harvey). *Lectotype.*—TCD (Alg. Aus. Exs. 578).

Distribution.—From Cottesloe, W.A., to Warrnambool, Vic. Hawaii.

Codium muelleri Kützing 1856: 34, pl. 95, fig. 2. J. Agardh 1887: 42. De Toni 1889: 493. Lucas 1912: 171; 1936: 54, fig. 36. Reinbold 1897: 45; 1899: 41. Schmidt 1923: 51. Setchell 1940: 444. Silva 1951: 91, 92, 94, fig. 10. Sonder 1880: 38. Womersley 1950: 145; 1953: 36.

Codium tomentosum sensu Sonder 1852: 660 (in part as to Lefebre Peninsula specimens). Wilson 1892: 188.

Codium schmidtii Vouk 1935: 9, pl. 1.

C. harveyi and *C. australicum* have been confused previously under *C. muelleri*. Records of the latter are therefore unreliable unless the specimens concerned have been checked. The above records of Agardh, De Toni, Lucas, Reinbold, and Sonder probably apply in part only, and the following are based on *C. harveyi* or *C. australicum*: Guiler 1952: 75. Lucas 1928: 10. May 1938: 212. Wilson 1892: 188.

Type locality.—Lefebre Peninsula, S.A. (F. v. Mueller). *Type.*—L (No. 937,337–772). Isotypes in MEL.

Distribution.—From Fremantle, W.A., around southern Australia to Rivoli Bay, S.A. *C. muelleri* is usually found on moderate to fairly calm coasts.

Codium perrinae Lucas 1935: 203, fig. 4. Guiler 1952: 75. Womersley 1950: 145.

Codium bursa sensu Guiler 1952: 75 (in part, as to Bellerive specimen).

Type locality.—Low Head, Tas. (Perrin and Lucas). *Type.*—CANB (herb. Lucas).

Distribution.—Stenhouse Bay, Yorke Peninsula, and D'Estrees Bay, Kangaroo I., and Nora Creina, in South Australia, and Low Head and Bellerive, Tas. This is apparently a rare species but probably more widespread. It occurs in upper sublittoral pools on rough reefs.

Codium pomoides J. Agardh 1894: 100. Lucas 1936: 53, fig. 33. Schmidt 1923: 36. Wilson 1892: 188. Womersley 1950: 146.

Codium bursa sensu (in part) Guiler 1952: 75. Harvey 1863: synop. 738. Lucas 1912: 171; 1913: 59; 1928: 10; 1929: 46. Sonder 1880: 38. Wilson 1892: 187.

Type locality.—"Southern Australia" (J. B. Wilson)—probably near Port Phillip. *Type.*—Should be in LD (herb. Agardh), but not located there.

Distribution.—From Eucla, W.A., to Walkerville, Vic., and around Tasmania.

Harvey distributed *C. pomoides* as *C. bursa?* var. *australis* (575 from Port Fairy, in MEL). See also under *C. mamillosum.*

Codium spinescens Silva & Womersley 1956.

Type locality.—10 miles east of Eucla (on South Australian–Western Australian border) (Womersley). *Type.*—AD (No. A19240). Isotype in UC.

Distribution.—Known from Houtman's Abrolhos (BM), Israelite Bay (MEL), and Torpedo Rocks, Yallingup (Royce 616, PERTH), W.A., and the type locality.

Codium spongiosum Harvey 1854: 565; 1858*a*: pl. 55; 1863: synop. 736. J. Agardh 1887: 38; 1894: 99. De Toni 1889: 489. Guiler 1952: 75. Lucas 1912: 171; 1935: 202; 1936: 51, fig. 32. May 1938: 212; 1951: 92. Schmidt 1923: 32, figs. 14 and 15. Sonder 1880: 38. Wilson 1892: 188. Womersley 1950: 146.

Type locality.—King George's Sound, W.A. (Harvey). *Lectotype.*—TCD (Alg. Aust. Exs. 577).

Distribution.—From Point Cloates, W.A., around southern Australia to Green I. (near Cairns), Qld., and around Tasmania. South Africa; Mauritius; New Caledonia; Lord Howe I.; Hawaii. Harvey gave no specific locality in his 1854 description, but gave King George's Sound, W.A., in 1859 as the first locality.

Genus HALIMEDA Lamouroux

Halimeda cuneata Hering in Krauss 1846: 214. Barton 1901: 15, pl. 1, figs. 7–14. De Toni 1889: 526. Kützing 1849: 505.

Halimeda macroloba Harvey 1854: 564; 1863: pl. 267, synop. 732. Sonder 1880: 38.
Halimeda obovata Kützing 1858: 11, pl. 25, fig. 1. J. Agardh 1887: 86. De Toni 1889: 523.
Halimeda versatilis J. Agardh 1887: 86. De Toni 1889: 524.

Type locality.—Natal, South Africa. *Type.*—B (lost?).

Distribution.—Tropical Australia and the Indian Ocean, extending as far south as Carnac I. and Cape Riche (Harvey record) in Western Australia.

Genus PSEUDOCODIUM Weber van Bosse

Pseudocodium australasicum Womersley 1955: 390, figs. 5 and 6.

Type locality.—Point Sinclair, S.A. (Womersley). *Type.*—AD (No. A13618).

Distribution.—Only known from the type locality and about 10 miles east of Eucla (on the South Australian–Western Australian border).

Genus RHIPILIOPSIS A. & E. S. Gepp

Rhipiliopsis peltata (J. Agardh) A. and E. S. Gepp 1911: 45, figs. 118–122. Lucas 1912: 170. Printz 1927: 315. Womersley 1950: 146.

Udotea peltata J. Agardh 1887: 74. De Toni 1889: 509. Wilson 1892: 188.

Type locality.—Port Phillip Heads, Vic. (Wilson). *Type.*—LD (herb. Agardh No. 15800).

Distribution.—Only known from Port Phillip Heads and Pennington Bay, Kangaroo I.

Order SIPHONOCLADALES

Family VALONIACEAE

Genus DICTYOSPHAERIA Decaisne

Dictyosphaeria sericea Harvey 1854: 565; 1860*b*: 339, pl. 196*A*: 1863; synop. 752. J. Agardh 1887: 118; 1896: 61. De Toni 1889: 371. Guiler 1952: 74. Lucas 1912: 167; 1928: 9; 1936: 31, fig. 13. Murray 1892: 19. Reinbold 1899: 41. Sonder 1880: 39. Tate 1882: 93. Wilson 1892: 188. Womersley 1950: 143; 1953: 36.

Dictyosphaeria favulosa sensu Sonder 1852: 660 (not Decaisne).

Type locality.—Western Australia (Clifton). *Type.*—TCD. In the original description Harvey gave "King George's Sound, Cape Riche and Rottnest" as localities. In TCD are two specimens from Cape Riche and one from "W. Aus." only, and the latter appears to be Harvey's earliest specimen.

Distribution.—From Rottnest I., W.A., to Western Port, Vic., and the north coast of Tasmania. (Derwent River is also given by Guiler (1952: 74), but this is doubtful.)

Family SIPHONOCLADACEAE

Genus APJOHNIA Harvey

Apjohnia laetevirens Harvey 1855*a*: 335; 1858*a*: pl. 5; 1863: synop. 751. J. Agardh 1887: 105–8. De Toni 1889: 382; 1896: 231. Levring 1946: 216. Lucas 1912: 167; 1936: 30, fig. 12. May 1945: 121. Printz 1927: 261. Reinbold 1897: 45; 1899: 41. Sonder 1880: 39. Wille 1897: 149; 1911: 111. Wilson 1892: 188. Womersley 1950: 144.

Type locality.—Phillip I., Western Port, Vic. (Harvey). *Type.*—TCD.

Distribution.—From Elliston, S.A., to Collaroy, N.S.W., possibly in Tasmania (Lucas).

Struvea scoparia (Kützing 1866: 1, pl. 2, fig. 1; J. Agardh 1887: 109) from New Caledonia is given by Murray and Boodle (1888: 266) as a synonym of *A. laetevirens*. Kützing's figure is very similar to the latter, but the opposite ramuli in his figure *d* are not typical. The occurrence of *A. laetevirens* in New Caledonia seems unlikely, but further collections are needed to prove or disprove this record.

Genus CLADOPHOROPSIS Borgesen

Cladophoropsis bulbosa Womersley 1955: 391, figs. 8 and 9.

Type locality.—Queenscliff, Vic. *Type.*—MEL.

Distribution.—Only known from the type locality and from Pennington Bay, Kangaroo I., S.A.

Cladophoropsis herpestica (Montagne) Howe 1914: 31.

Conferva herpestica Montagne 1842: 15; 1845: 6.
Cladophora herpestica Kützing 1849: 415. De Toni 1889: 347.
Aegagropila herpestica Kützing 1845: 14, pl. 66.
Cladophoropsis howensis Lucas 1935: 197.

Type locality.—Bay of Islands, New Zealand (Hombron). *Type.*—PC (herb. Montagne).

Distribution.—New Zealand; Lord Howe I.; Japan. Point Peron, W.A.; head of Great Australian Bight to Encounter Bay, S.A.; Clarence River, N.S.W.; Stradbroke I., Qld. This species is probably more widespread along southern Australia, at least on the warmer coasts. On the west coast of Eyre Peninsula it forms extensive mats in the lower littoral and uppermost sublittoral in shaded parts of reefs on moderate to rough coasts.

Type material of *C. howensis* Lucas is identical with New Zealand specimens of *C. herpestica.*

Cladophoropsis magnus Womersley 1955: 390, fig. 7.

Type locality.—Smoky Bay, S.A. (Womersley). *Type.*—AD (No. A13615).

Distribution.—Smoky and Denial Bays, west coast of Eyre Peninsula, S.A.

Family BOODLEACEAE

Genus STRUVEA Sonder

Struvea plumosa Sonder 1845: 50; 1846: 151; 1880: 39. J. Agardh 1887: 109. Harvey 1854: 564; 1858*a*: pl. 32; 1863: synop. 750. Kützing 1856: 31, pl. 90. Lucas 1912: 167. Murray and Boodle 1888: 265–82, pl. 16, fig. 1. Printz 1927: 267. Wille 1897: 150, fig. 101; 1911: 113. Womersley 1950: 144.

Struvea macrophylla Harvey 1854: 564; 1858*a*: pl. 7; 1863: synop. 749. J. Agardh 1887: 109. De Toni 1889: 365. Lucas 1912: 167. Murray and Boodle 1888: 265–82, pl. 16, fig. 2. Sonder 1880: 39.

Valonia radicans Grunow in Piccone 1884: 293.

Type locality.—Western Australia (Preiss). *Type.*—MEL.

Distribution.—From Champion Bay, W.A., to Victor Harbour, S.A.

The type of *S. macrophylla* is in TCD (herb. Harvey). *S. plumosa* and *S. macrophylla* have previously been considered distinct species, differing in size and net pattern. On comparing a range of specimens and following their development it seems certain, however, that *S. macrophylla* is only a large, old state of *S. plumosa.* The early development of *S. plumosa* has been described by Murray and Boodle. The primary stem consists when young of an elongate, clavate vesicle, and this stage was described by Grunow as *Valonia radicans* (type in W). From the older stem, opposite primary branches arise, and each cell of these produces from its upper part 2 opposite secondary branches, which lie in much the same plane and grow to touch the primary branch above or below, where the end adheres to the corresponding cell one above the cell of origin. At this stage the plant would be called *S. plumosa.* As the primary branches grow, the secondary branches become further separate, and the latter also divide into a number of cells. At this stage the secondary branches form a zig-zag between the primary. Following this, the cells of the secondary branches produce opposite tertiary branches, which grow across to join the next secondary branch. This pattern, with the primary and secondary branches more elongate and the whole frond larger in size, is what Harvey called *S. macrophylla.*

It is significant that *S. macrophylla* has only been known as old, large plants, and *S. plumosa* as small, young ones. Frond development is apparently a summer occurrence. In winter the plant consists of a mass of primary stems, without any upper branched part, and further development commences in early summer. The larger "*macrophylla*" fronds have probably been collected from the drift in late summer, having developed in calmer pools.

On the west coast of Eyre Peninsula (westwards at least to the head of the Bight), *S. plumosa* occurs as dense masses in shaded areas at the base of cliffs, usually at the rear of reefs, where wave action is moderate to severe.

Order DASYCLADALES

Family DASYCLADACEAE

Genus ACETABULARIA Lamouroux

Acetabularia peniculus (R. Brown in Turner) Solms-Laubach 1895: 27, pl. 2, figs. 2, 6, and 7. May 1938: 213. Womersley 1950: 144.

Fucus peniculus R. Brown in Turner 1819: 78, pl. 228.

Polyphysa aspergillosa Lamouroux 1816: 252, pl. 8, fig. 2. Endlicher 1843: 17. Kützing 1849: 510; 1856: 32, pl. 92, fig. 2.

Polyphysa peniculus (R. Brown in Turner) C. Agardh 1821: 473; 1824: 192. J. Agardh 1887: 161. Cramer 1887: 35, pl. 5, fig. 16. De Toni 1889: 421. Guiler 1952: 75. Harvey 1854: 564; 1858*a*: pl. 11; 1863: synop. 744. Kützing 1843: 311. Lucas 1912: 168. Sonder 1880: 38. Wille 1897: 156, fig. 106. Wilson 1892: 189.

Polyphysa cliftoni Harvey 1858*a*: under pl. 11; 1863: pl. 255, synop. 745. J. Agardh 1887: 161. De Toni 1889: 422. Lucas 1912: 168. Sonder 1880: 38.

Type locality.—King George's Sound, W.A. (R. Brown). *Type.*—BM.

Distribution.—From Fremantle, W.A., around southern Australia to Newcastle, N.S.W., and around Tasmania. This species is confined to very calm bays and inlets where it grows on old shells on a muddy or sandy bottom.

Solms-Laubach retained *P. cliftoni* as a variety of *A. peniculus*, though it is probably only a larger and more strongly developed form.

Genus DASYCLADUS C. A. Agardh

Dasycladus densus Womersley 1955: 392, figs. 10 and 11.

Type locality.—Point Fowler, S.A. (Womersley). *Type.*—AD (No. A19437).

Distribution.—Only known from the type locality.

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THE FAMILIES RISSOINIDAE AND RISSOIDAE (MOLLUSCA) FROM THE SOLANDERIAN AND DAMPIERIAN ZOOGEOGRAPHICAL PROVINCES*

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Summary

This paper reviews taxonomically the whole, as far as is known, of the families Rissoinidae and Rissoidae (Mollusca) from northern Australia, with the addition of a number of species from Christmas Island in the Indian Ocean. The area covered includes two zoogeographical provinces, the Solanderian and the Dampierian. All species, known or proposed as new, are figured and discussed. In all, 167 species and subspecies belonging to 47 genera are reviewed, of which 131 species and subspecies and 27 genera are proposed as new. Of these, 123 come from the Solanderian Province and 37 from the Dampierian, and 6 Peronian species are now recorded from the Solanderian. Eight species were found common to the Solanderian and Dampierian. Eighteen species are described from Christmas I.

I. Introduction

(*a*) *Area Covered*

This is the second paper dealing with individual families of Mollusca from northern Australia. The area covered includes two recognized zoogeographical provinces: the Solanderian, extending from just north of Brisbane to southern New Guinea, including the Coral Sea and Torres Strait, and the Dampierian, extending westwards of Torres Strait along the northern shore of Australia. Of the five zoogeographical provinces recognized in Australia, these two have many common features. Both have tropical faunas, and are associated with and form a connecting link between the Indian Ocean and the western Pacific. The three southern provinces on the other hand are not only temperate and cool temperate, but are practically isolated from the rest of the world, and their relationship is more with the Tertiary of southern Australia than with other living faunas. It is felt that in this and all future work on the Mollusca, it is better to consider the north and south of Australia as separate entities rather than to treat Australia as one zoogeographical unit.

The opportunity has also been taken to include a small collection from Christmas Island, a true oceanic island in the Indian Ocean south of Java. How far this is part of an endemic fauna is not yet known, but among the small shells it contains many startling novelties. On the whole these have a generic but rarely specific connexion with those of the Dampierian Province, but much more work must be done before any conclusions on relationship can be reached.

(*b*) *Material*

One of the great difficulties has been to acquire sufficient material for comprehensive study. Though shells have been extensively collected from the area by many people over a considerable period of time, interest has been more in large shells, and with an eye to beauty rather than to scientific value. Small shells, under half an inch in size, have been largely neglected, even though in individual numbers they form the bulk of the molluscan population, and in number of species probably more than three-quarters of the whole. Thus, though large collections of shells from Queensland and the Barrier Reef are dispersed in museums and private collections throughout the world, it is believed, as far as the families dealt with here are concerned, that practically all the material collected during the last 75 years has been studied. Much of this is in the Australian Museum, Sydney, collected largely by the late Charles Hedley and a few others who were fired by his enthusiasm. Unfortunately some, particularly the minutae, is in bad condition, owing to the sweating of the glass tubes, and part is quite destroyed. Nothing of importance is in either the National Museum of Victoria, nor the South Australian Museum, the only other two institutions in Australia where much work on conchology has been done.

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* Material from Christmas Island in the Indian Ocean is also dealt with.

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Fortunately much of the deficiency has been made good by a large collection made at Darwin during the war years by the author's son John Laseron. This, as far as is known, is the only systematic collection of small shells from the Dampierian Province yet made. The same collector has also made extensive collections from Bowen, Gladstone, Hervey Bay, the Capricorn Group, and other localities in Queensland, which included many rissoids. A further large collection was made by T. Iredale from Michaelmas Cay in northern Queensland, and though from one isolated locality this proved extraordinarily rich in rissoids, containing a large proportion of the known and many undescribed species. Miss G. Thornley has also collected in the Torres Strait area and obtained some rissoids, extending the range of some species and adding one striking new genus and species.

All in all it is felt that sufficient has been gathered to give a fairly comprehensive picture of the rissoid fauna of the Solanderian, and at least an idea of that of the Dampierian. Though the list is probably far from complete, most of the common, and therefore ecologically the most important, species are now described and figured, and this should form a foundation for future work.

Figure 1 shows localities from which collections were made.

(c) *Previous Work*

In view of the size and importance of the two families very little work has been done on the northern Australian rissoids. In the latter part of the last century a fair amount of attention was paid by European writers to the rissoinas of the world and to a lesser extent the Rissoidae, including such comprehensive monographs as that by Boettger (1887) and Tryon (1887). But much of this work was very poor in quality, and that of Tryon particularly is full of errors and even misquotations of earlier authors. This left the group in the utmost confusion. Much of its neglect in later years is no doubt due to this cause, and most conchologists have since given it the most cursory attention, applying the names already in use indiscriminately and often after the most casual examination.

The work of Arthur Adams is typical of much of his times: no designation of types, description confined to a few lines of Latin which omitted most of the essential specific characters, and no figures. Other authors were just as bad. Melvill and Standen of the British Museum were a little better; the descriptions were still inadequate but they did provide figures, even though the lithographs were far too small and indistinct to reveal essential details (Melvill and Standen 1895, 1897, 1898).

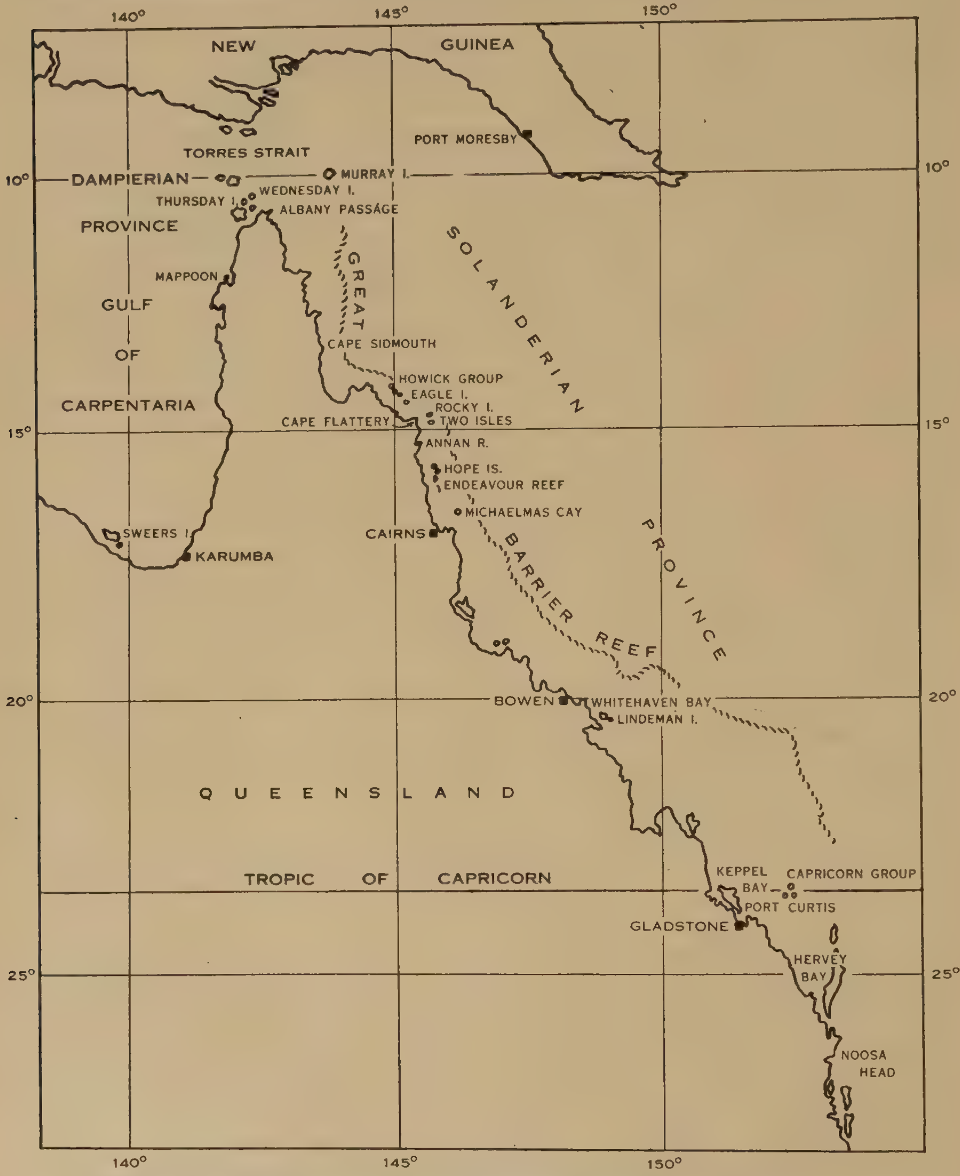
140°
145°
150°
NEW
GUINEA
PORT MORESBY
TORRES STRAIT
10°
DAMPIERIAN
MURRAY I.
WEDNESDAY I.
THURSDAY I.
ALBANY PASSAGE
PROVINCE
SOLANDERIAN
MAPPOON
GREAT
GULF
OF
CARPENTARIA
CAPE SIDMOUTH
HOWICK GROUP
EAGLE I.
ROCKY I.
TWO ISLES
CAPE FLATTERY
15°
ANNAN R.
HOPE IS.
ENDEAVOUR REEF
MICHAELMAS CAY
SWEERS I.
KARUMBA
CAIRNS
BARRIER
REEF
PROVINCE
20°
BOWEN
WHITEHAVEN BAY
LINDEMAN I.
QUEENSLAND
TROPIC OF CAPRICORN
KEPPEL BAY
CAPRICORN GROUP
PORT CURTIS
GLADSTONE
HERVEY BAY
25°
NOOSA HEAD

Fig. 1.—Map showing localities (other than Christmas I.) and Darwin from which material was obtained.

The treatment of Australian species was rather more fortunate. Work in southern waters by Tate, May, Gatliff, and Gabriel was on the whole good and clear, and Frauenfeld (1867) described some Peronian species fully and with excellent figures. Watson (1886) was another notable exception. In his monumental work on the material gathered by the Challenger Expedition he described a number of Australian species in great detail, and provided splendid illustrations of adequate size. In this century the work of the late Charles Hedley stands out from that of his contemporaries; present-day conchologists owe much to his careful and painstaking efforts, and particularly to the faithful exactness of his drawings. In 1901 he figured all the types of Brazier's species described from the collections of the Chevert Expedition, and later described other Queensland rissoids from the Hope Is., Mast Head Reef, and other localities. A few Western Australian species were also described by Thiele (1930).

In later years more generalized papers by various authors have produced reasonable order in both families in southern temperate waters. Powell (1927) described new species and discussed genera particularly from the Neozelandic Province. Cotton (1944, 1952) reviewed the Flindersian and Maugean species and followed Hedley (1910) in listing Queensland forms. The Peronian species were described and figured by Laseron (1950). The present paper now extends the general review to the Solanderian and part of the Dampierian Province. The only remaining gap is the extreme north-west and parts of Western Australia, and when this is bridged, both families will have been taxonomically reviewed for the whole of Australasia.

From all these sources 22 species of rissoids were described from Queensland, and about as many more extra-territorial species recorded (Hedley 1910). Most of the latter have now, however, to be rejected. It has been found that for the most part the records were made on the most superficial resemblances. The same species has frequently been recorded under more than one name; at other times the same foreign name has been applied to several Australian species which in no way resemble each other. A few records have been retained, but where there is doubt it is felt that it is far better to omit a name rather than perpetuate an error which can lead to quite erroneous conclusions on questions of faunal relationship.

(*d*) *Summary of Present Work*

In all 167 species and subspecies belonging to 47 genera are now discussed and figured, of which 131 species and subspecies and 27 genera are proposed as new. Species on the Queensland list found in Moreton Bay are here omitted, as they are all Peronian forms, and Moreton Bay is now accepted as within the limits of the Peronian Province. Of the 167 species 123 are inhabitants of the Solanderian Province and 37 of the Dampierian, and 18 come from Christmas I. None of the last has been found in Australian seas, but 8 species have been found common to the Solanderian and Dampierian, and 6 Peronian species have been noted for varying distances within the Solanderian. Of these, 2, one with slight racial variation, extend right round the Australian coast from southern New South Wales to Darwin.

II. CLASSIFICATION

The general classification here adopted is provisional, and cannot in any sense be considered final. All the material examined has been dead for a considerable time; most of it came from beaches or dredgings, and a very small proportion originally had been collected alive. There is thus no information about the living animals, and even the operculum has not been available for study.

Early conchologists were content to use the name Rissoidae to cover a few widely defined genera, but later workers have recognized two main families: Rissoidae, with simple, thin, paucispiral opercula, and Rissoinidae, in which the operculum is provided with a spur or appendage. For the few European species this is satisfactory, inasmuch as their animals, opercula, and radulae are known; but for the vast number of non-European species, particularly from the tropics, it is almost inevitable that ultimately this will be found to be quite inadequate. It is expected that within the Rissoidae alone there are many groups of genera which, when their anatomy and life history become known, will constitute separate families, some of which may have little if any relationship at all. Even from the shell alone it is hard to link such thin translucent genera as *Diala* and *Obtortio* with the minute solid *Scrobs*, *Anabathron*, and others, or with the strongly sculptured *Merelina*. The use of the names Rissoidae and Rissoinidae for the present must, therefore, be considered one of convenience only, and true phylogenetic relationships must be deferred until more data become available. What is initially important is that the numerous species should be figured and described, and thus be given an identity on which future research can be based.

Within the families the question whether many or few genera should be admitted is still controversial. In the latter half of the 19th century, when the controversy on evolution was at its height, many authors looked on the original Linnaean genera as almost sacrosanct, and the introduction of new genera as something like heresy. It was not realized that a genus is not a natural unit but a term of convenience to link together a number of related species, presumably descended from a common ancestor —the degree of relationship necessary to form a genus largely depending on the opinion of the author. Amongst the conchologists particularly reluctant to admit new genera there were two schools. English conchologists like Smith and Watson retained a few old genera in the widest sense; others like the American Dall split the genera into numerous subgenera, and these again into sections, each of which was given a name. The latter procedure is particularly confusing. Given a subspecific or racial name as well, it is possible for a single form to have as many as five names, resulting in a clumsy nomenclature which is moreover hardly in keeping with accepted binomial practice.

The old genus *Rissoina*, the basis of the family Rissoinidae, has suffered particularly from this plethora of subgeneric and sectional names. At one stage *Rissoina* was retained for practically all the species, with a number of subgenera, indicated in brackets. Later on some authors admitted some of the subgenera as full genera, but retained others as subgenera or even as sections of subgenera. Furthermore no two authors agreed as to just how this grouping should be applied. For instance Cossman and Peyrot (1919) use *Phosinella* Morch as a section of *Rissoina*, while *Zebina* H. & A. Adams becomes a section of the subgenus *Zebinella* of the genus *Rissoina*. *Schwartziella* Nevill and *Moerchiella* Nevill on the other hand are given full generic status. Other authors give quite different values to all these names. As the characters of *Zebina* are quite as distinctive as those of *Schwartziella* and *Moerchiella*, there seems no reason why one should be called a subgenus and the others genera.

To obviate further confusion all subgeneric and sectional designations are here entirely discarded, and only fully generic names used. The selection of a generic name means that a group of species have such characters in common that close relationship is suggested, and that the same combination of characters in further species will enable them to be placed in that genus. Even then there is the danger that relationship is often more apparent than real, and that parallel development has obscured true lineage. How far this is so only future research can decide. In the meantime numerous small genera which are clearly defined are far less likely to confuse other workers than large, cumbersome genera containing many incongruous elements.

All types, paratypes, and specimens illustrated, if not already in the Australian Museum, Sydney, have now been presented to that institution.

III. DESCRIPTION OF SPECIES

Family RISSOINIDAE

KEY TO THE AUSTRALIAN GENERA OF THE FAMILY RISSOINIDAE

1.	Without sculpture	*Zebina* H. & A. Adams
	Sculpture of axial ribs only	2
	Sculpture both axial and spiral	8
	Sculpture discrepant	17
	Sculpture spiral, axial sculpture when present very faint	18
2(1).	Without basal fold	3
	With basal fold, ribs strong and oblique	7
3(2).	Ribs few, strong, and oblique. No columella sinus	4
	Ribs straight	5
	Ribs fine and numerous	6
4(3).	Elongate, varix wide over columella, protoconch often subulate	*Pandalosia*, gen. nov.
	Short, stout, protoconch short	*Schwartziella* Nevill
5(3).	Columella sinus present	*Austrosina*, gen. nov.
	No sinus, ribs rising above suture in spires, aperture distorted	*Palisadia*, gen. nov.
6(3).	Large, ovate, with columella sinus	*Peripetella*, gen. nov.
	Minute, broad, ribs obliquely forward to suture, no sinus	*Contraxiala*, gen. nov.
7(2).	Columella sinus slight to medium	*Costalynia*, gen. nov.
	Columella sinus open anteriorly to form pseudo-canal	*Fractoralla*, gen. nov.
8(1).	Sculpture not cancellate, axials thin to nearly obsolete, spirals thin and numerous	9
	Sculpture strongly cancellate	12
	Spiral sculpture of 2 strong keels	15
9(8).	Aperture triangular	10
	Aperture not triangular	11
10(9).	Whorls flat, angled at base	*Pleneconea*, gen. nov.
	Whorls rounded	*Zymalata*, gen. nov.
11(9).	Whorls flat	*Apataxia*, gen. nov.
	Whorls rounded	*Condylicia*, gen. nov.
12(8).	Shells large, over 8 mm	*Phosinella* Morch
	Shells small, under 6 mm	13
13(12).	Columella sinus slight to medium	14
	Columella sinus open anteriorly to form pseudo-canal	*Isselia* Schmeltz
14(13).	Apex fine, sometimes subulate	*Phintorene* Iredale
	Apex broad	*Planapexia*, gen. nov.
15(8).	Shell narrow	16
	Shell broad and short	*Herewardia* Iredale
16(15).	Spirals tuberculate	*Pyramidelloides* Nevill
	Axials strong, spirals wide apart, not tuberculate	*Costabieta*, gen. nov.

17(1).	Large, elongate, many whorls, varix weak	*Moerchiella* Nevill
	Short, turreted, varix strong	*Dentrissoina*, gen. nov.
18(1).	Sculpture of fine threads	19
	Sculpture of strong spiral ribs	20
19(18).	No basal fold	*Dipsotoma*, gen. nov.
	With basal fold	*Lucidinella*, gen. nov.
20(18).	Ribs subequal	*Pellamora* Iredale
	Peripheral rib forming keel	*Chrystella*, gen. nov.

Genus SCHWARTZIELLA Nevill

Schwartziella Nevill, 1881, p. 162.

Type species *Rissoina orientalis* Nevill. Type species altered (Nevill 1884, p. 73), *Rissoina bryerca* Mont. In his latter work Nevill either overlooked his previous choice or preferred another type—probably the latter, for among the species listed under *Schwartziella*, Nevill synonymized his own *orientalis* and two other species under *triticea* Pease (Pease 1862). If the synonymy was justified, *Rissoina triticea* would, of course, now become the type of *Schwartziella*, but apparently *orientalis* is quite a good species and should be retained, not only as a species but as the type of the genus. The type locality is Ceylon.

From *S. orientalis* the following generic characters can be given for *Schwartziella*: Small rissoinids of stumpy appearance with distant, oblique axial ribs. The body whorl is relatively long, the penultimate whorl short and swollen. There is no basal fold; the aperture is simple with no sinus on the columella, and is fortified by a heavy margin. The protoconch is short and swollen, of 1½ whorls, the nucleus large.

SCHWARTZIELLA INCONSPICUA (Brazier)

Figs. 2 and 3

Rissoina inconspicua Brazier, 1877, p. 367. Hedley, 1901, pl. 17, fig. 29.

The type, collected by the Chevert Expedition, came from the Torres Strait. The species is also widespread along the Great Barrier Reef as far south as the Capricorn Group. Specimens in the Australian Museum (C29514) are from Murray I. Others studied came from Michaelmas Cay and from other islands in the vicinity of Cairns. The figures are taken from a long series collected by J. Laseron from Heron I. in the Capricorn Group. Figure 3 is typical and matches the type in every detail. Its length was 2·8 mm. From the same series a number of larger specimens were separated which are not quite typical, having an extra whorl and being slightly narrower (Fig. 2). That illustrated is 3·7 mm in length. In all other characters this is identical with the typical form.

SCHWARTZIELLA LATA, sp. nov.

Fig. 4

Shell small, broadly conical with a convex spire, white, shining, and translucent. Protoconch small, of 2½ smooth whorls, the initial 1½ whorls as in *S. inconspicua* but relatively smaller. Mature whorls 5, the body whorl large, the penultimate whorl short and swollen, margins rounded, sutures moderately deep. Sculpture of strong, distant axial ribs, 12 to the whorl, not rounded but narrowed at their summits, continuous to the base. Aperture ovate, angled posteriorly, the varix narrow on the outer margin, fading anteriorly but wider over the columella. Length 3·2 mm.

*Locality.**—Christmas I., holotype and 9 paratypes.

Remarks.—In general characters this is very close to *S. inconspicua*, but it is relatively broader and can at once be separated by the protoconch.

Genus PANDALOSIA, gen. nov.

Type species *Pandalosia excelsis*, sp. nov.

Resembling *Schwartziella* in its sculpture of prominent, curved, and oblique axial ribs, but with elongated, rather delicate small shells, the varix very strong and greatly developed over the columella into a thickened plate, protoconchs small and glassy and sometimes subulate.

Pandalosia includes a well-defined group of small shells ranging throughout the tropical waters of Australia and into the South Pacific and Indian Oceans. The difference between the numerous species is not great, but the species seem remarkably constant and restricted in geographical range. Among shell characters for specific determination, the number of whorls, the number and size of the axial ribs and the details of the aperture are all important, but differences in the form and size of the protoconch will be found the most useful guide. None of the Australian species seems to have been previously described.

PANDALOSIA EXCELSIS, sp. nov.

Fig. 5

Shell small, elongate, conical, white, shining, and translucent. Protoconch slender, of 2½ whorls, the nucleus large, sculpture beginning gradually on the 3rd whorl. Mature whorls 6, short, rounded, sutures deeply impressed. Sculpture of large, rounded axial ribs, curved and oblique, 14 on the body and penultimate whorls, fewer on the earlier whorls. Aperture semicircular, anteriorly and laterally extended, very oblique, the anterior margin thrust forward, varix very heavy, widest over the columella, where it is indented by the termination of the axial ribs, inner margin only slightly arched. Length 3·7 mm.

Localities.—Murray I. (C. Hedley), holotype and 5 paratypes; Barrier Reef off Cairns (D. Pitt; C46088 in Australian Museum).

Remarks.—This beautiful little species has been selected as the type of the genus, as it shows perfectly all the characters considered to be of generic value.

PANDALOSIA DARWINENSIS, sp. nov.

Fig. 6

Shell small, slender, conical, white, glassy, and translucent. Protoconch slender, of 2½ rounded whorls, nucleus large, practically identical with that of *P. excelsis*. Mature whorls 5, rounded, sutures deeply impressed. Sculpture as in *P. excelsis*, but the axial ribs are smaller. They also number 14 on the body and penultimate whorls. The aperture is also similar to that of *P. excelsis*, but is not quite so thickened on the outer margin, and the varix is even more widely extended over the columella. Length 3·4 mm.

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* Apart from Darwin (Northern Territory) and Christmas I. (Indian Ocean), all localities mentioned are on or near the coast of Queensland unless otherwise indicated. See Figure 1.

Locality.—Darwin (J. Laseron), holotype and 6 paratypes.

Remarks.—This is so close to *P. excelsis* that opinions might differ as to whether the differences are fully specific or merely racial. In all the specimens examined, however, the characters are constant, *P. darwinensis* has 1 whorl less, is smaller, and the aperture is slightly different.

PANDALOSIA SUBULATA, sp. nov.

Fig. 7

Shell small, elongate, conical, white, glassy, and translucent. Protoconch subulate, slender, glassy, of 3½ whorls, mature sculpture beginning abruptly. Mature whorls 5, rounded, sutures impressed. Sculpture as in the previous species, but the ribs finer and more numerous, numbering 16 on the body whorl. Aperture also as in the previous species, but the varix not so heavily developed on the outer margin. This may be accounted for by age, as the specimen from Michaelmas Cay has the outer margin more thickened. Length 3·3 mm.

Localities.—Heron I., Capricorn Group (J. Laseron), holotype; Michaelmas Cay (T. Iredale).

Remarks.—This species is very close to both *P. excelsis* and *P. darwinensis*, but differs from both by its longer, slender, subulate protoconch.

PANDALOSIA OCEANICA, sp. nov.

Figs. 8 and 9

Shell very small, conical, white, and translucent. Protoconch large and subulate, smooth, conical, of 5 whorls, the apex acuminate, the penultimate whorl swollen, adult sculpture beginning abruptly. Mature whorls 3½, rounded, sutures deep. Sculpture of a few large, rounded, oblique axial ribs, curving in to the sutures, 13 on the body whorl, 11 on the penultimate whorl. Aperture semicircular, extended laterally and anteriorly, very oblique, the anterior margin thrust forward. Varix wide and prominent, very wide over the columella, where it is indented by the termination of the ribs. Length 2·3 mm.

Locality.—Christmas I., holotype and 23 paratypes.

Remarks.—This and the preceding 3 species are all closely related, and from the data available afford an excellent example of geographical differentiation, *oceanica* from the Indian Ocean, *darwinensis* from the Arafura Sea, *excelsis* from Torres Strait, and *subulata* from the Barrier Reef, southern Queensland. *P. oceanica* is the smallest of all, it has fewer whorls, and the peculiar protoconch is quite distinctive. The only other example among the rissoinids of a nearly similar protoconch is that of *Rissoina ephamella* Watson from 40 fm off Honolulu (Watson 1886, Plate 46, Fig. 6), but this differs in other characters, particularly the possession of a basal fold. In Watson's work, though the description of *R. ephamella* is indexed as occurring on p. 617, it has evidently been inadvertently omitted from the text.

PANDALOSIA OBTUSA, sp. nov.

Figs. 10 and 11

Shell relatively large for the genus, elongate, conical, white, and translucent. Protoconch smooth, large, and short, of 1½ whorls only, the nucleus small, the next whorl large and elongate, sculpture beginning gradually. Mature whorls 5, rounded, sutures deep. Sculpture as in the previous species, of strong, curved, oblique, rounded axial ribs, 12 on each of the body and penultimate whorls. Aperture semicircular, very oblique with the anterior margin thrust forward. Varix very strong and thick and wide over the columella where it is indented by the axial ribs. Length 3·8 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype and 2 paratypes.

Remarks.—This is the largest of all the species here discussed, but again it is the distinctive protoconch which makes its separation certain.

PANDALOSIA DELICATULA, sp. nov.

Fig. 12

Shell small, elongate, conical, white, vitreous, shining, and translucent. Protoconch subulate, conical, continuing the line of the spire, smooth, of 3½ whorls, mature sculpture beginning abruptly. Mature whorls 5, regular, rounded, sutures fairly deep. Sculpture of relatively thin, curved, oblique axial ribs, about 17 to the whorl, continuous to the base. One rib on each of the penultimate and body whorls is slightly more prominent than the others, suggesting a periodicity in growth and the formation of previous complete apertures. Aperture ovate, the varix not large, the outer margin slightly sinuous, the varix wider over the columella but less so than is usual in the genus. Length 3 mm.

Locality.—Christmas I., holotype and 2 paratypes.

Remarks.—This is readily distinguishable from other species by the protoconch, which is stouter than that of *P. subulata*, by the finer and more numerous axial ribs, and by the aperture.

Genus AUSTROSINA, gen. nov.

Type species *Rissoina pulchella* Brazier.

Elongate shells with sculpture of distant, nearly straight, rather thin axial ribs, sometimes evanescent on the base, fine spiral sculpture also sometimes present on the base, no basal fold. Aperture arcuate with a pronounced columella sinus, varix strong on outer margin, but not developed over the columella as in *Pandalosia*. Protoconch of 3 short whorls, smooth.

Of the Indo-Pacific genera this approaches nearest to the original *Rissoina* D'Orbigny. The type of *Rissoina*, *R. inca* D'Orbigny, came from Bolivia, and is a stouter shell with a different texture, and stronger, more oblique axial ribs, spiral sculpture between the ribs, but with a similar aperture. The protoconch of *Austrosina*, though of the same type as found in at least one other group of rissoinids, can here be considered, in conjunction with other characters, as having generic value.

AUSTROSINA PULCHELLA (Brazier)

Fig. 13

Rissoina pulchella Brazier, 1877, p. 367. Hedley, 1901, p. 127.

Rissoina honoluluensis Watson, 1886, p. 619, pl. 46, fig. 9.

The type locality is the Barnard Is., Queensland. Watson's *honoluluensis* came from the Sandwich Is., but he also recorded it from Torres Strait. There is no doubt that the latter specimens are Brazier's *pulchella*, thus justifying Hedley's synonymy for this area, but there is some doubt that these are the same as those from the Sandwich Is. Watson's figure and description are certainly very close to the Australian species, but without actual specimens for comparison it is impossible to confirm their identity, and *honoluluensis* may yet have to be restored for the eastern Pacific.

Several specimens of *pulchella* were sorted from material from Michaelmas Cay, and can be taken as typical, though the very faint spiral threads between the axial ribs are only visible on some of the specimens under a strong light, and are apparently removed by the slightest wear. The specimen figured is 5·1 mm in length.

AUSTROSINA QUINITA, sp. nov.

Fig. 14

Shell small, elongately conical, solid, white. Protoconch conical, smooth and glassy, of 3 short whorls, incipient sculpture appearing on the 3rd. Mature whorls 5, increasing regularly, rounded, sutures moderately impressed. Sculpture of axial ribs, which are heavier than those of *A. pulchella* but about the same number, 15 to the whorl, barely reaching the suture but continuous to the base. Aperture arcuate, acutely angled posteriorly, a rounded sinus on the columella, varix strong on the outer margin, its outer surface composed of a number of the axial ribs which are narrowed and packed closely together, varix on the inner margin narrow and not produced over the columella. Length 3·8 mm.

Locality.—Christmas I., holotype and 11 paratypes.

Remarks.—This species is very close to *A. pulchella*, but it is smaller with 1 whorl less, and the axial ribs, though about the same in number, are heavier and a little oblique.

AUSTROSINA EVANIDA, sp. nov.

Fig. 15

Shell small, conical, solid, white. Protoconch conical, smooth, glassy, of 3 short whorls, the middle whorl rather larger than is shown in the figure, sculpture beginning gradually. Mature whorls 5, increasing regularly, rounded, sutures moderately deep, the body whorl slightly restricted at the base. Sculpture of numerous thin axial ribs, about 28 to the whorl, just reaching the suture and fading on the base. At the base of the penultimate and just below the periphery on the body whorl fine spiral threads begin to develop, and closely packed together persist right to the base. Aperture arcuate, angled posteriorly, oblique, the anterior margin thrust forward, varix present but not heavy, columella with a shallow sinus. Length 3·7 mm.

Locality.—Christmas I., holotype.

Remarks.—This is a broader shell than either of the preceding species, it has a different contour, and the axial ribs are thinner and more numerous, fading on the base, where they are replaced by the spiral threads. The varix is also less prominent.

Genus COSTALYNIA, gen. nov.

Type species *Rissoina cardinalis* Brazier.

Conical, elongated shells, with sculpture of distant, oblique axial ribs as in *Schwartziella*, but with a prominent spiral fold on the base, which continues on the back of the shell and merges into the varix. Columella with a distinct sinus. Protoconch short, generally turbinate, of 1½ whorls, or it may be reduced to about half a whorl immersed in the summit. Normally there is no spiral sculpture, but 2 species, here rather doubtfully included, have 2 spiral cords on the base which override the axial ribs.

Gould (1860, p. 401) introduced *Rissolina* for somewhat similar shells, separating them from *Rissoina* by "the acute, elevated ridge with an adjacent construction round the back, and with a predominance of longitudinal folds". From the species listed by Gould the type was designated by Nevill (1884, p. 77) as *Rissoina plicatula* Gould from Loo Choo I. in the Philippines. The description of this species states that the axial ribs are crossed by incised lines, and as all the Australian species are without this character, it alone justifies their separation.

COSTALYNIA CARDINALIS (Brazier)

Figs. 16 and 17

Rissoina cardinalis Brazier, 1877, p. 368. Hedley, 1901, p. 127.
Rissoina mercurialis Watson, 1886, p. 618, pl. 46, fig. 8.

The type locality is given as 20 fm off Cape Grenville, and Watson described his *mercurialis* from nearby in the Torres Strait. He can be pardoned for overlooking Brazier's species for it was unfigured, and it was not until Hedley reviewed and figured all the types in the Macleay Museum collected by the Chevert Expedition that the synonymy became apparent.

The specimen of Figure 16 was collected by Hedley from Two Isles off Cape Flattery (C41440, Australian Museum) and labelled *Rissolina crassa*, a Peronian species which it in no way resembles. It is 6 mm long. A long series from Michaelmas Cay shows that the species varies in size and width, and a specimen only 4·2 mm in length is here figured for comparison (Fig. 17). In all other characters it is identical, and it is considered that the difference is due to individual variation and is not even racial.

COSTALYNIA TORRESIANA, sp. nov.

Fig. 18

Shell of medium size, conical, slightly turreted, solid, white with traces of a pale brown band on the periphery and on the base of the earlier whorls. Protoconch of 3 short, glassy whorls, the 3rd with a median keel and terminated by a varix. Mature whorls 5, short, with a narrow shelf below the sutures, slightly rounded, a very strong spiral fold on the base of the body whorl. Sculpture of strong, slightly oblique axial ribs, with deep channels between and rising to narrow summits, overriding the basal fold and about 16 to the whorl. Aperture ovate, angled at the columella, the columella sinus deep and rounded, the varix very heavy and wide, its outer surface crossed by 5 heavy cords. Length 4·6 mm.

Locality.—Murray I. (C. Hedley), holotype and 1 paratype.

Remarks.—This species can be readily distinguished from *C. cardinalis* by the protoconch, the heavier shell with shorter whorls, the more numerous ribs, and the heavier basal fold and varix, and by the transverse cords on the outer surface of the varix.

COSTALYNIA ISOLATA, sp. nov.

Fig. 19

Shell of medium size, conical, solid, white. Protoconch short, relatively large, smooth and vitreous, of 1½ whorls, the nucleus large, the next whorl inflated, sculpture beginning gradually on the 3rd whorl. Mature whorls 6, short, increasing regularly, slightly rounded. Sculpture of strong, rounded axial ribs, slightly oblique, bending in at the sutures, 14 on the penultimate and 16 on the body whorl. Base with a strong spiral fold indented by the termination of the axial ribs. Aperture broadly arcuate, with a moderately strong varix thinning internally at the anterior margin, columella sinus shallow. Length 4·3 mm.

Locality.—Christmas I., holotype and 4 paratypes.

Remarks.—This species differs from the previous 2 species by the shorter whorls and the more numerous and rounded ribs, and by the protoconch.

COSTALYNIA DECAPITATA, sp. nov.

Fig. 20

Shell small, conical, heavy, white and translucent, shining. Apex truncate, at first sight appearing broken, close microscopic examination only revealing the protoconch as a relatively large nucleus immersed in the summit. Mature whorls 5, increasing regularly, rounded, restricted at the sutures. Sculpture of strong, rounded, oblique axial ribs, very close together, about 16 to the whorl. Basal fold strong, indented by the termination of the axial ribs. Aperture semicircular, large, laterally extended, oblique, the anterior margin thrust well forward. Varix heavy, columella sinus shallow but distinct. Length 3·2 mm.

Locality.—Michaelmas Cay, holotype and 3 paratypes.

Remarks.—The small size, the large expanded aperture, the close axial ribs, and the peculiar protoconch separate this at once from all the previous species.

COSTALYNIA TRUNCATA, sp. nov.

Fig. 21

Shell small, broadly conical, solid, yellowish white to pale yellow-brown. Apex broadly truncate, at first sight appearing broken, protoconch of about half a whorl with a large nucleus, partially immersed in the summit. Mature whorls 4, well rounded, increasing regularly, restricted at the sutures. Sculpture of very large axial ribs, very oblique and curved, 12 to the whorl, basal fold strong and fused to the varix on the inner margin. Aperture ovate, large and laterally expanded, very oblique and thrust well forward anteriorly, columella sinus very slight, varix very heavy and thickened internally. Length 2·9 mm.

Locality.—Darwin (J. Laseron), holotype and 2 paratypes.

Remarks.—This species resembles *C. decapitata* and differs from all the other species here discussed by the peculiar protoconch. The apex is, however, even wider and more truncate than in *decapitata*; the shell is smaller, has 1 whorl less, is relatively broader, has a different aperture, and has fewer and larger axial ribs.

COSTALYNIA DUX, sp. nov.

Fig. 22

Shell large, broadly conical, solid, white. Protoconch broken but apparently short. Mature whorls 6 or 7, increasing regularly, slightly rounded, body whorl comparatively large. Sculpture of distant, straight, well-elevated axial ribs with narrow edges, separated by broad, rounded channels, bending in to the sutures, and continuous from whorl to whorl. Basal fold strong, separated by a deep furrow, and indented by the terminations of the axial ribs. Aperture large, triangular, oblique, outer margin not thickened internally, but with a broad, external, smooth varix. Anterior margin flattened, angled at the columella. Columella sinus moderately deep with a reflected margin. Length 11 mm.

Locality.—Holotype selected from 3 specimens in Australian Museum (C9400) collected by C. Hedley from Green I.

Remarks.—This is by far the largest of all the species of *Costalynia* here discussed. In sculpture and general characters it resembles *C. cardinalis*, but is twice the size and, in particular, has quite a different aperture.

COSTALYNIA BIRESTES, sp. nov.

Figs. 23 and 24

Shell relatively large, conical, elongate, solid, white. Protoconch small, smooth, and glassy, of 1½ whorls, the nucleus small, sculpture beginning gradually on the 2nd whorl. Mature whorls 7, short, only slightly rounded, increasing regularly. Sculpture of narrow, elevated, nearly straight axial ribs, curving into a deep basal furrow and overriding the strong basal fold in thickened nodules. In addition to the axial ribs, 2 sharp spiral cords appear on the base and override the ribs. Aperture ovate, oblique, the anterior margin well thrust forward, the margin fortified by a wide varix which is not greatly thickened internally, and which on its exterior surface is crossed by 6 curved ribs (Fig. 24). On the base preceding the formation of the varix the axial ribs are greatly enlarged and thickened. Columella sinus deep. Length 7 mm.

Localities.—4–14 fm, Albany Passage, Torres Strait (C. Hedley), holotype and 1 paratype; Lindeman I., common; Michaelmas Cay (T. Iredale).

Remarks.—The 2 spiral cords on the base in this and the next species *C. bilinea* separate these from all other species of *Costalynia*, and might possibly justify generic separation. The series from Lindeman I. show a slight variation in the number of axial ribs but conform otherwise to the type.

COSTALYNIA BILINEA, sp. nov.

Figs. 25 and 26

Shell of medium size, solid, conical, white. Protoconch of 3 short whorls, smooth and glassy, sculpture beginning gradually on the 3rd whorl. Mature whorls 5, margins slightly rounded and restricted at the sutures. Sculpture of strong, rounded axial ribs, close together, slightly oblique and curved, 16 to the whorl, becoming narrow and crowded behind the varix. In addition to the axial sculpture, 2 very fine spiral threads circle the base and override the axial ribs. The slightest wear removes these threads and they are not visible on some specimens. Basal fold strong and overridden by the axial ribs. Aperture oval and oblique, thrust forward at the anterior margin. Varix strong and wide, thickened internally, externally covered with closely packed ridges, corresponding to a fusion of the axial ribs. Columella sinus wide and shallow, impinging on the anterior margin. Length 4·2 mm.

Localities.—Murray I., holotype and 5 paratypes; Michaelmas Cay (T. Iredale), common.

Remarks.—The 2 spiral threads on the base suggest close relationship with *C. birestes*, but it is smaller, with fewer whorls, thicker axial ribs, and a different protoconch, and the sculpture on the exterior of the varix is axial in direction instead of spiral. Specimens from Michaelmas Cay are rather larger than the type, averaging about 5 mm in length. On occasional specimens the axial ribs become smaller and more crowded on the body whorl, but this seems the limit of the variation.

Genus FRACTORALLA, gen. nov.

Type species *Fractoralla praecida*, sp. nov.

Like other genera with strong axial ribs and a basal fold which have previously been included in *Rissolina*, but differing in the aperture. In *Fractoralla* the columella sinus is so pronounced and anteriorly situated that it breaks through the anterior margin, leaving a gap between the outer varix and the columella, simulating the true anterior canal found in such families as Cerithiidae, Triphoridae, etc. In previous descriptions most authors have used the term canaliculate when referring to this character, which is not strictly correct and can be misleading. Here the term *pseudo-canal* has been substituted, as at least suggesting a different function. Amongst the clathrate Rissoinidae, species with a similar pseudo-canal have been previously separated under the name *Isselia* Schmeltz (1874).

FRACTORALLA PRAECIDA, sp. nov.

Fig. 27

Shell of medium size, nearly cylindrical, the spire with very little taper and an obtuse, dome-shaped apex, white and shining. The protoconch is large, of less than a whole whorl, planoid, and partially immersed in the summit. Mature whorls 4, nearly flat, only slightly restricted at the sutures. Sculpture of strong, rounded, oblique axial ribs, 16 to the whorl, thinning and bending in just below the sutures, forming an ill-defined band, particularly on the penultimate whorl. Basal fold strong and well defined, overridden by the axial ribs. Aperture relatively small and ovate, oblique and thrust forward anteriorly, thickened internally, and fortified by a strong varix formed by the enlargement and fusion of the final axial ribs. The varix widens anteriorly, and then ends abruptly to form one margin of the pseudo-canal. The columella is twisted backwards to form the other margin. Length 5·8 mm.

Locality.—Darwin (J. Laseron), holotype and 1 paratype.

Remarks.—There should be no difficulty in the future recognition of this species, even though both the type and paratype are slightly worn. Its best recognition point, however, the blunt, dome-shaped apex, may also cause it to be overlooked as at first sight the shell appears as if broken.

FRACTORALLA TRANSITA, sp. nov.

Fig. 28

Shell of medium size, conical, white, and translucent. Protoconch large, of 1½ smooth whorls, the nucleus large, the next whorl almost cylindrical. Mature whorls 5, increasing regularly, slightly rounded. Sculpture of rather narrow, elevated axial ribs, slightly oblique, thinning below the sutures, 16 to the whorl. Basal fold strong, overridden by the axial ribs and merging with the columella, which is obliquely truncate, forming one margin of the pseudo-canal. Aperture ovate, inner margin sinuous, outer margin fortified by a heavy, wide varix, exteriorly crossed by 5 strong cords. The varix narrows anteriorly, terminating abruptly to form the other margin of the wide pseudo-canal. Length 5·7 mm.

Locality.—Darwin (J. Laseron), holotype.

Remarks.—This species has been based on a single specimen, but its characters are so distinctive that there should be no difficulty in its future recognition. It differs from *F. praecida* in form, in protoconch, and in the details of the aperture, particularly the varix.

FRACTORALLA DECIPIENS, sp. nov.

Fig. 29

Shell of medium size, elongate, conical, solid, white, and shining. Protoconch continuing the line of the spire, of 1½ smooth whorls, the nucleus large, the next whorl nearly cylindrical. Mature whorls 6, increasing regularly, slightly rounded. Sculpture of well-elevated, oblique axial ribs, narrowed at their summits, about 15 to the whorl. Basal fold well defined, the axial ribs overriding it after crossing the deep separating channel, the fold distinct from the columella. Aperture ovate, fortified externally with a wide, heavy varix, the exterior of which is finely axially striate and not crossed by cords. The varix terminates abruptly as in other species to border the pseudo-canal. Inner margin sinuous, the columella not truncate, but the sinus anteriorly reflected to itself form the pseudo-canal. Length 6·3 mm.

Localities.—Curtis I., Port Curtis (J. Laseron), holotype and 3 paratypes; Heron I., Capricorn Group (J. Laseron).

Remarks.—This species resembles *F. transita* from Darwin in general form, but differs by being larger, with 1 whorl more, and by the features of the aperture. A good distinguishing feature is the exterior of the varix, crossed by cords in *transita*, and with axial striations in *decipiens*.

FRACTORALLA HERONENSIS, sp. nov.

Figs. 30 and 31

Shell of medium size, conical, solid, white. Protoconch small, cap-like, glassy, of 2½ whorls, the 1st 1½ whorls planoid and protruding outwards, the next smaller, mature sculpture appearing suddenly. Mature whorls 7, short, nearly flat. Basal fold strong, overridden by the axial ribs and separated from the columella by a groove. Sculpture of strong, slightly oblique axial ribs, well elevated with narrow summits, 14–16 to the whorl. Aperture arcuate, fortified by a strong varix, which is externally finely striate and formed by the fusion of the final axial ribs. Anteriorly the varix terminates in 2 projections as seen from in front, which are caused by the termination of the basal fold and which border the pseudo-canal. Inner margin sinuous, the columella sinus reflected over the columella, and open anteriorly to produce the pseudo-canal. Length 6 mm.

Localities.—Heron I., Capricorn Group (J. Laseron), holotype and 4 paratypes; 17–20 fm, Mast Head I. (C. Hedley), the last labelled *Rissolina obeliscus* Schwartz.

Remarks.—This is very close to *F. decipiens*, and could be easily taken for that species were it not for the peculiar protoconch, dissimilar to that of any other rissoinid so far examined.

Genus PERIPETELLA, gen. nov.

Type species, *Peripetella queenslandica*, sp. nov.

This genus is proposed for medium-sized littoral species, generally coloured and often gregarious under stones. The form is broadly ovate, the spire slightly convex, the sutures shallow. The sculpture is of numerous fine axial ribs, continuous to the base, the aperture is ovate, the varix when present is broad but not heavy, and the columella sinus is pronounced. The Peronian species *Rissoina variegata* A. Adams will come here.

Nearest to *Peripetella* is Iredale's *Caporista* (1955, p. 81), but this is a deep-water group, the shells are even broader and of a different shape, and the ribs are thinner and far apart, with fine spiral sculpture between.

PERIPETELLA QUEENSLANDICA, sp. nov.

Fig. 32

Shell of medium size, ovate, with slightly convex spire, colour uniformly brown. Protoconch very small, of 2 whorls, colourless, smooth and glossy, without a varix. Mature whorls 7, the body whorl long, margins very slightly curved, sutures shallow. Sculpture of numerous well-defined, rounded, narrow axial ribs, separated by channels about the same width, about 35 to the whorl, persistent to the base, which is without a fold. On the base fine spiral threads appear between the ribs, but fade on the upper portion of the whorls. Aperture ovate, fortified by a wide but not thick varix, composed externally by the thinning and close packing of the axial ribs. Columella deeply sinuate, the inner margin covered by a narrow callus, not visible at the angle at which the figure is drawn. Length 7 mm.

Localities.—Bowen, alive under stones (J. Laseron), holotype and 4 paratypes; Lindeman I., abundant; Murray I.; Michaelmas Cay, etc.

Remarks.—This is one of the commonest and most widespread species in Queensland, occurring both on the mainland coast and on the Barrier Reef. It has been variously labelled in collections as *Rissoina variegata* A. Adams, *R. ambigua* Gould, *R. multicostata* Garratt, and other names, all originally ill defined, only one of which, *R. variegata*, can definitely be ascribed to Australia. It is certainly not the Peronian *variegata*, and it seems far better to give it a new and definite identity than to link it doubtfully with some species from a distant locality.

PERIPETELLA IMMERSA, sp. nov.

Fig. 33

Shell of medium size, ovate, spire slightly convex, colour very pale brown, often faded to white. Protoconch very small, of less than a whorl, planoid and immersed in the summit, so that at first sight the apex seems broken, particularly in worn specimens. Mature whorls 6, slightly rounded, sutures shallow, the body whorl long. Sculpture as in *P. queenslandica*, but the axial ribs are fewer and wider, about 25 to the whorl, and there are no spiral threads between them on the base. Aperture also similar to *queenslandica*, but the varix is heavier and the outer margin rather more expanded. Length 6·3 mm.

Localities.—Rocky Is., Cape Flattery (C. Hedley), holotype and 4 paratypes; Michaelmas Cay, Bowen, etc.

Remarks.—This has much the same range as and is generally associated with *P. queenslandica*, with which it can easily be confused. Worn specimens are difficult to identify, except that *immersa* is a little broader, with 1 whorl less and with coarser sculpture. The protoconch is, however, the deciding factor, and where this is unbroken the separation of the species is easy.

PERIPETELLA LINEARIS, sp. nov.

Fig. 34

Shell small, elongate, narrow, spire slightly convex, colour brown. Protoconch slender, subulate, of 3½ flat whorls, white, smooth, and glassy. Mature whorls 6, nearly flat, sutures shallow, body whorl long, no basal fold. Sculpture of well-defined, rounded, straight axial ribs, bending in to the base, 16 to the whorl. Aperture semicircular, slightly expanded, fortified with a wide but not thickened varix, inner margin with a slight callus, hardly visible from in front, the columella with a shallow sinus. Length 3·3 mm.

Locality.—Heron I., Capricorn Group (J. Laseron), holotype.

Remarks.—The brown coloration, shallow sutures, long body whorl, straight, narrow axial ribs, and characters of the aperture conform to *Peripetella* as defined; but it is much smaller and narrower than the previous species, the axial ribs are fewer and farther apart, and the protoconch is quite distinct.

Genus APATAXIA, gen. nov.

Type species *Apataxia erecta*, sp. nov.

This genus is proposed for a group of elongate, conical shells, with straight sides and very shallow sutures, the sculpture of straight, generally narrow axial ribs which are indented by spiral striae. The aperture is relatively small and not expanded, and the varix is absent or only slight. There is no basal fold, and the columella sinus is deep. In the species here assigned to this genus the protoconch is of uniform type, conical and of 3 short whorls.

APATAXIA ERECTA, sp. nov.

Fig. 35

Shell small, regularly conical, colour pale ochre, bleaching to white. Protoconch small and conical, ochre in colour, of 3 short whorls, the last much larger than the others. Mature whorls 7, short, with nearly flat sides, the sutures hardly impressed. Sculpture of straight, well-defined, narrow axial ribs, continuous to the base, about 20 to the whorl. The spiral sculpture consists of sharply incised striae which cross the axial ribs and indent them. There are 9 of these striae on the body whorl and 5–6 on the earlier whorls. The aperture is relatively small, the outer margin not expanded. thick, but without a varix. Columella sinus rounded. Length 4·2 mm.

Localities.—Heron I. (J. Laseron), holotype; Barrier Reef off Cairns (D. Pitt); Michaelmas Cay (T. Iredale); Darwin (J. Laseron), and other localities.

Remarks.—This well-defined species has a wide range, and is very constant, the only variation noted being that the mature whorls vary from 6 to 7.

APATAXIA ERIPONA, sp. nov.

Fig. 36

Shell small, regularly conical, white. Protoconch in the type slightly worn, but relatively large, the 1st 2 whorls smooth, sculpture beginning gradually on the 3rd. Mature whorls 6, increasing regularly, nearly flat, sutures not impressed. Sculpture of straight axial ribs, defined and well raised, becoming weaker on the base, 16 to the whorl. Spiral sculpture of narrow channels, about 9 on the body whorl, which cross the intercostal spaces and indent the axial ribs. Aperture arcuate, no external varix, but the outer margin thickened. Inner margin sinuous with a deep, anteriorly placed sinus. Length 3·8 mm.

Locality.—Port Moresby, New Guinea (J. Laseron), holotype and 3 paratypes.

Remarks.—Closely allied to *A. erecta*, but broader, with fewer and stronger axial ribs, deeper spiral striae, and a different protoconch.

Genus PLENECONEA, gen. nov.

Type species *Pleneconea angulata*, sp. nov.

Shell conical with flat sides, angled at the periphery. Sculpture of numerous straight axial ribs continuous to the base, which are overridden by fine spiral threads. Aperture subtrigonal, expanded, with a small posterior sinus, no columella sinus but the anterior corner widely reflected, varix strong.

In sculpture this approximates to *Apataxia*, but the sharply angled whorls and different aperture give it a quite different facies. There is also no columella sinus. The genus *Parazebinella* Boettger (1893, p. 108), the type of which, *P. crenilabris* Boettger, comes from the Philippines, has a similar angulation, and though unfigured, is described as having costate sculpture on the upper whorls, but the lower whorls spirally striate only.

PLENECONEA ANGULATA, sp. nov.

Fig. 37

Shell of medium size, conical, broad at base, white. Protoconch of 3 short, smooth, glassy whorls, continuing the line of the spire, sculpture beginning gradually on the 4th whorl. Mature whorls 6, short, the 1st 2 slightly rounded, later whorls flat, body whorl angled at the periphery, flat and sloping below to the base, sutures not impressed. Sculpture of numerous straight axial ribs, about 32 to the whorl, rounded, separated by narrow channels, continuous to the base, and with blunt terminations at the sutures. Spiral sculpture of fine, closely packed threads, which cross the axial ribs. Aperture subtrigonal, oblique and laterally curved forward anteriorly, fortified with a wide and fairly heavy varix. There is no columella sinus, but the varix thins anteriorly, and the anterior margin at its angle is reflected widely. Length 5·2 mm.

Locality.—Lindeman I. (sorted from material collected by C. Hedley), holotype and 13 paratypes.

Remarks.—The angular body whorl at once distinguishes this from all other species so far examined from Australian seas, and this alone should make its future recognition easy.

Genus PHOSINELLA Morch

Phosinella Morch, 1876, p. 57.

Type species, designated by Nevill (1884, p. 83), *Rissoina pulchra* C. B. Adams. Morch's diagnosis of *Phosinella* as a subgenus reads: "T. reticulata, apertura profunde sinuata, opercula apophysi, styliforme, postice denticulis". This very wide definition, if literally applied, will cover all of the very great number of clathrate species living in the Atlantic, Pacific, and Indian Oceans. Some differentiation is undoubtedly necessary to simplify the classification. Before the introduction of *Phosinella*, Schmeltz (1874) had in fact proposed *Isselia* for clathrate species with peculiar apertures simulating an anterior canal. Iredale (1955) proposed *Phintorene* for small Australian tropical species approximating closely to the true *Phosinella*. Still another group of Australian species can be recognized. These are short, broad species, of few whorls, with peculiar planoid protoconchs, and for these *Planapexia* is later proposed.

The type of *Phosinella* comes from the West Indies, and is a large shell, one of its features being the strong basal fold and the very deep, anteriorly placed columella sinus. To discriminate between this and the other 3 clathrate genera the principal characters may be summarized as follows:

Phosinella.—Over 8 mm in length, mature whorls 7 or over.

Phintorene.—Under 6 mm in length, mature whorls under 7.

Planapexia.—Mature whorls 4–6, apices blunt.

Isselia.—Aperture with pseudo-canal.

PHOSINELLA CURTISI (Smith)

Figs. 38 and 39

Rissoina curtisi Smith, 1884, p. 63, pl. 5, fig. M.

Considerable difficulty was experienced in identifying this species. Smith's description and figure, though adequate as far as they went, were unfortunately based on a single broken specimen with only 4 whorls remaining. As a result the name has at different times been applied to several different species from the Queensland coast. Specimens in the Australian Museum (C27360), from 5 to 10 fm, Hope Is., are marked "compared with type", and it can be assumed that these are correctly identified. The specimen here figured is from the type locality, Port Curtis, and is identical with the Hope Is. specimens. It too is not quite perfect, lacking the protoconch and possibly 1 or 2 whorls, but it has 7 whorls remaining and a perfect aperture. The axials number about 24 on the body whorl and there are 5 spirals. The basal fold is strong. The length is 11 mm. The aperture is very oblique and well thrust forward anteriorly. The varix is strong on the outer margin, but is interrupted anteriorly where the margin is formed by the continuation of the basal fold, and is thin and reflected. Other imperfect specimens of the species have been seen from Lindeman I. and Michaelmas Cay.

PHOSINELLA TERES (Brazier)

Fig. 40

Rissoina teres Brazier, 1877, p. 367. Hedley, 1901, pl. 17, fig. 27.

The type figured by Hedley is in the Macleay Museum, Sydney, is 7 mm long, and came from 4 fm off Cape York. That now figured is from 4 to 14 fm, Albany Passage, virtually the same locality, and is 8 mm long. This agrees exactly with Hedley's drawing though the protoconch is missing. The protoconch in the type is small, of 2 glassy whorls. The sculpture is distinctive, both the axials and the spirals being thin, and rising above their intersections in small, sharp nodules. There are 4 spirals on the body whorl and 18 axials. The aperture is very similar to that of *P. curtisi*.

PHOSINELLA CYATHA, sp. nov.

Figs. 41–43

The holotype is not perfect, and the number of whorls is computed from an immature specimen of 7 whorls, and the protoconch from a juvenile (Fig. 43). Shell very large, elongate, conical, dull greyish white. Protoconch slender, continuing the line of the spire, of 2½ glassy whorls, the nucleus large, sculpture beginning gradually on the 3rd whorl. Mature whorls about 9, of which 5 remain on the holotype, rounded, restricted at the sutures, body whorl with a deep channel at the base separating the small basal fold. Sculpture regularly clathrate, the axials and the spirals both thin, the spirals overriding the axials and rising at the intersections into small nodules. The axials are numerous; there are 26 axials and 8 spirals on the body whorl, and 6 spirals on the penultimate whorl. Of the spirals the 3rd and 4th from the suture are weaker and closer together than the others. On the base the axials are continuous across the channel and the basal fold. Aperture large, semicircular, laterally expanded, very oblique and thrust forward anteriorly, outer margin with a heavy varix, disappearing where the margin is formed by the termination of the basal fold, columella sinus moderately deep. Length of holotype 11 mm, estimated complete length of shell 15 mm, of juvenile (Fig. 43) 3·5 mm.

Locality.— 4–14 fm, Albany Passage (C. Hedley), holotype and 2 paratypes.

Remarks.—This is by far the largest of the Australian rissoinids so far examined. It resembles *P. teres* in many characters, but can readily be distinguished by the more numerous axials.

Genus PHINTORENE Iredale

Phintorene Iredale, 1955, p. 81.

Type species *Rissoina allanae* Laseron.

There is no fundamental difference between *Phosinella* and *Phintorene* except in size, the former all being 8 mm or more in length, the latter 6 mm or less. Nevertheless the species grouped around the type *P. allanae* seem a natural genus and closely related to each other. The species are constant but not easy to separate, and close microscopic examination is always necessary. Differences are determined by variation in the protoconchs, which are generally small and glassy, of 2 or 3 whorls; the form ranges from medium to slender, the clathration varies in coarseness, the number and disposition of axials and spirals varies between species, and there are small differences in the apertures. All the species have a varix and a columella sinus, and most have a basal fold, but in the type and some other species this is replaced by the enlargement of the basal spirals, which are smooth and not tuberculate.

PHINTORENE ALLANAE (Laseron)

Fig. 44

Rissoina allanae Laseron, 1950, p. 261, fig. 5.

The type locality is Woolgoolga, north coast of New South Wales, where the species is probably a migrant from the more northern Solanderian Province. It is actually one of the commonest species on the Queensland coast, both on the reef and the mainland, localities ranging from the Capricorn Group to Port Moresby in New Guinea. West of Torres Strait there is some variation, and specimens from Darwin are now designated as a separate race. The specimen here figured is from Heron I. in the Capricorn Group, collected by J. Laseron, and 3·8 mm in length.

P. allanae is one of several species which in the past have been labelled as *Rissoina exasperata* Souverbie, a New Caledonian species of uncertain identity. Hedley (1899, p. 418, Fig. 10) doubtfully recorded *exasperata* from Funafuti, and in view of the uncertainty published a good figure and description, at the same time extending the range to the Queensland coast, and synonymizing under *exasperata*, *R. quasillus* Melvill & Standen (1897, p. 308, Plate 11, Fig. 65), also from New Caledonia. However, none of the Queensland shells so far examined agrees with Hedley's figure and description of the Funafuti shell, so whether that is the true *exasperata* or not is outside the scope of this paper. It seems far better to expunge *exasperata* from the Australian list.

P. allanae is remarkably constant throughout its range, and no difference can be detected between specimens from the type locality and from Queensland, except a little in size, some specimens ranging to a little over 4 mm in length.

PHINTORENE ALLANAE PROXIMA, subsp. nov.

Fig. 45

A number of specimens collected by J. Laseron from Darwin approximate the typical *allanae* in essential characters but show minor but constant differences, suggesting that the species has undergone local modification and constitutes a separate geographical race. The main difference is that the Darwin specimens have 6 instead of 5 mature whorls, and may have slightly more axials and an additional spiral on the body whorl, making the clathrate sculpture closer. The figure of the holotype chosen shows the extreme of this sculpture, but all specimens do not show it in the same degree. Length 3·8 mm.

PHINTORENE APICINA, sp. nov.

Figs. 46 and 47

Shell of medium size, conical, yellowish white. Protoconch relatively large, white and glassy, of 1½ whorls, nucleus large, the next whorl swollen, sculpture appearing gradually on the 3rd whorl. Mature whorls 6, short, rounded, sutures impressed. Sculpture strongly clathrate, axials stronger than the spirals, well elevated, rising at the intersections into small tubercles. The axials number 16 on the penultimate and 18 on the body whorl, and are continuous from whorl to whorl; the spirals are 4 on the penultimate and 8 on the body whorl, the 2 lowest smooth and enlarged, replacing the basal fold. Aperture ovate and very oblique, well thrust forward anteriorly, outer margin not extended, slightly thickened internally and with a broad external varix. Columella sinus deep, adjacent to the anterior margin. Length 4·8 mm.

Localities.—Facing I., Port Curtis (H. L. Kesteven), holotype; Bowen (J. Laseron), common.

Remarks.—In its general characters this species is almost identical with *P. allanae*, from which it is almost indistinguishable. It is, however, somewhat larger, but the main and definite difference is in the protoconch.

PHINTORENE ULTIMA, sp. nov.

Fig. 48

Shell of medium size but large for the genus, elongate, narrow, conical, creamy white. Protoconch of 2½ short whorls continuing the line of the spire, nucleus relatively large, sculpture beginning gradually on the 3rd whorl. Mature whorls 7, rounded, sutures impressed. Sculpture strongly clathrate, the axials stronger than the spirals, rising into ill-defined nodules at the intersections. The axials number 18 on the body whorl, but are fewer on the early whorls. The spirals number 3 on the early whorls and 5 on the body whorl, and there is a strong fold on the base, overridden by the axial ribs. Aperture ovate, only slightly oblique and not expanded laterally, the outer margin thickened internally, and with a strong, wide external varix, fading towards the anterior margin. Columella sinus very deep at the anterior extremity. Length 5·8 mm.

Locality.— 4–14 fm, Albany Passage, holotype sorted from material collected by C. Hedley.

Remarks.—This is a well-defined species, larger, more elongate, and narrower than *P. allanae*, with 2 additional whorls, a different protoconch, and fewer spirals.

PHINTORENE CAELATA, sp. nov.

Fig. 49

Shell of medium size, conical, elongate, solid, white. Protoconch of 3 short, smooth, glassy whorls, continuing the line of the spire. Mature whorls 6, sides nearly flat, deeply channelled at the sutures, body whorl with only a slight curve to the base. Sculpture rugosely clathrate, the axials, 18 on the body whorl, stronger than the spirals, which number 5 on the body whorl and 3 on the earlier whorls. The axials are broad, and rise at the intersections into prominent, rounded gemmules, the interstices forming small, deep pits. Basal fold strong, indented by the axial ribs, which are continuous across the intervening deep channel. Aperture ovate, slightly oblique, outer margin thickened internally, and with a very broad external varix which is crossed by a continuation of the spiral ribs, columella sinus deep. Length 4·6 mm.

Locality.—Cape Sidmouth, holotype and 1 paratype selected from a series in the Australian Museum (C2662) collected by A. R. Henn.

Remarks.—This species has a similar protoconch to and the same number of axials and spirals as *P. ultima*, but is smaller, has a whorl less, is narrower, and the sculpture is much more rugose, the large gemmules at the intersections and the small, deep intervening pits giving it a very different facies.

PHINTORENE ANGUSTA, sp. nov.

Fig. 50

Shell relatively large, elongate, conical, white, and translucent. Protoconch relatively large, continuing the line of the spire, of 2½ smooth, glassy whorls, nucleus large. Mature whorls 6, slightly rounded. Sculpture of numerous close, rather fine axial ribs and spirals, rising at their intersections into small, rounded gemmules. The axials number about 24 to the whorl; the spirals are 9 on the body whorl and 5 on the earlier whorls. Basal fold strong, indented by the axial ribs which cross the intervening channel. Aperture ovate, slightly oblique and thrust forward anteriorly, outer margin slightly thickened internally, but with a broad, external varix, widest at its anterior end, and crossed by the continuation of the spirals. Columella sinus broad and placed at the anterior extremity. Length 5·5 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype.

Remarks.—This is the largest and narrowest species, and has finer sculpture than any of the other species here discussed. The protoconch is also different, and though the species is described from 1 specimen only there should be no difficulty in its future recognition.

PHINTORENE EMINA, sp. nov.

Fig. 51

Shell of medium size, conical, white, and translucent. Protoconch of medium size, of 2½ short, smooth, glassy whorls, the nucleus small, the next 2 whorls nearly equal. Mature whorls 6, nearly flat, the sutures channelled, body whorl with a gentle curve to the base. Sculpture of relatively few and distant axial ribs and spirals, the axials the strongest, rising at their intersections into medium-sized gemmules. The axials number 14 to the whorl; there are 5 spirals on the body whorl and 3 on each of the earlier whorls. The basal fold is strong, and indented by the axial ribs which cross the intervening channel. Aperture arcuate, oblique and thrust well forward anteriorly, outer margin slightly thickened internally and with a very wide, external varix, which is even wider at its anterior end, and crossed by the continuation of the spiral ribs. Columella with a deep sinus which is laterally reflected. Length of holotype 4·2 mm; other specimens vary from slightly under 4 to about 4·5 mm.

Locality.—Darwin (J. Laseron), holotype and 8 paratypes.

Remarks.—This resembles *P. allanae* in general form and appearance, but differs by having a protoconch about twice the size, by the additional whorl, and by the fewer axials and spirals.

PHINTORENE DIGERA, sp. nov.

Fig. 52

Shell small, conical, elongate, solid, white, and translucent. Protoconch conical, smooth and glassy, of 2½ short whorls. Mature whorls 5, slightly rounded, bending in sharply above to the sutures, body whorl sharply restricted at base. Sculpture strongly clathrate, the axials stronger and rising above the intersections in elongate tubercles, the spiral ribs lower and forming bars between the axials, axials continuous from whorl to whorl. The axials number 14 to the whorl, the spirals 3 on the earlier whorls and 4 on the body whorl, with another larger rib below the basal contraction, and several fused together at the columella. Aperture ovate, oblique, thrust forward anteriorly, laterally slightly expanded, outer margin thickened, fortified externally by a heavy, broad varix, on which the spiral ribs are continuous and the axials are small and closely packed. Columella sinus rounded and well defined. Length 3 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype and 7 paratypes.

Remarks.—This is closest to *P. emina*, but is smaller, with 1 whorl less, and slightly narrower; it has heavier axials, a different protoconch, and a slightly different aperture.

PHINTORENE PAENULA, sp. nov.

Fig. 53

Shell small, broadly conical, white, and translucent. Protoconch of medium size, short, of 1½ smooth, glassy whorls. Mature whorls 5, nearly flat, sutures shallow, body whorl relatively long. Sculpture widely clathrate, axials and spirals both thin and distant, rising at the intersections into fairly prominent, rounded gemmules. The axials number 14 to the whorl; there are 4 spirals on the body whorl, and 2 on each of the earlier whorls. Basal fold strong, nodulose from the termination of the axial ribs which cross the intervening furrow. Aperture ovate, oblique, outer margin not thickened internally, but with a wide external varix traversed by the continuation of the spirals. Columella sinus deep, its margin reflected. Length 3·8 mm.

Locality.—Darwin (J. Laseron), holotype and 6 paratypes.

Remarks.—Here again the protoconch is a good guide to the species, but the sculpture is also distinctive, the wide clathration and the smaller number of thin axials and spirals differing from all the other species discussed.

Genus PLANAPEXIA, gen. nov.

Type species *Planapexia fractura*, sp. nov.

Planapexia is proposed for a group of species with a distinct facies, but with clathrate sculpture similar to that of *Phintorene* and other genera. All are small, 6 mm or under, with few whorls, usually 4 but not more than 6, rather broad, the spire with little taper, the summits broad, the protoconch more or less planoid, of less than 1 whorl, either lying on or immersed in the summit, giving the shell a broken appearance. The basal fold is strong, the aperture has a strong varix, and the columella sinus is deep and may break through to the anterior margin.

The protoconch is here used as the main character for generic separation, even though a similar protoconch in other than clathrate species has not been used for the same purpose. Here in conjunction with other characters it seems of sufficient importance, and it certainly gives a distinct facies to what is apparently a natural group.

PLANAPEXIA FRACTURA, sp. nov.

Fig. 54

Shell small, broad, and slightly conical, the spire with very little taper, apex blunt, white, solid, slightly translucent. Protoconch planoid, of less than 1 whorl, fused within the summit. Mature whorls 4, slightly rounded, sutures indented, body whorl long. Sculpture strongly clathrate, the axials stronger than the spirals, 18 axials to the whorl, 7 spirals on the body whorl, 4 on the penultimate, 3 on each of the earlier whorls, the intersections producing small gemmules. Basal fold strong, sometimes double, tuberculate from the terminations of the axial ribs. Aperture ovate, oblique, outer margin fortified with a heavy and very wide varix, crossed by the continuation of the spiral ribs. Columella sinus deep. Length 3·5 mm.

Locality.—Darwin (J. Laseron), holotype and 27 paratypes.

Remarks.—This, like other species of the genus, appears at first sight to be broken at the apex, and it is only after close examination that the peculiar nature of the protoconch is apparent.

PLANAPEXIA DECEPTA, sp. nov.

Fig. 55

Shell of medium size, solid, broad, spire with very little taper, apex domed, white, and translucent. Protoconch as in *P. fractura*, planoid, of less than a whorl, fused within the apex. Mature whorls 4, slightly rounded and indented at the sutures, body whorl large. Sculpture regularly clathrate, the axials stronger than the spirals, the intersections marked by small, rounded gemmules. The axials are numerous, about 20 to the whorl. There are 4 spirals on each of the earlier whorls, and 11 on the body whorl, the last 3 separated by a deeper furrow from those above, and replacing the usual basal fold. Aperture ovate, oblique, thrust well forward anteriorly, outer margin with a wide, heavy varix, crossed by the continuation of the spiral ribs. Columella with a deep sinus with a widely reflected margin. Length 4·8 mm.

Locality.—Curtis I. (J. Laseron), holotype.

Remarks.—This is very close to *P. fractura* from Darwin, but is larger, broader, and with more numerous axials and spirals, making the clathration finer.

PLANAPEXIA sp.

Figs. 56 and 57

What appears to be still another species of *Planapexia* is a single, slightly worn specimen from Darwin, collected by J. Laseron. It is very close to *P. fractura* from the same locality but is nearly twice the size, its length being 6 mm. Unfortunately wear has removed the gemmules at the intersections of the spirals and the axials, leaving a reticulation of rounded, hollow pits. The specimen is here figured for future reference, but further material is needed to decide if it is a single aberration or another definite species.

PLANAPEXIA QUADRINA, sp. nov.

Fig. 58

Shell of medium size, spire with little taper, apex blunt, yellowish white, translucent. Protoconch of a large nucleus only, immersed in the summit, which is hollow within the revolution of the 1st mature whorl. Mature whorls 4, rounded, restricted at the sutures, body whorl relatively short. Sculpture strongly clathrate, the axials numerous, 20–22 to the whorl, the spirals few and stronger than the axials, the intersections rising into prominent, rounded, medium-sized gemmules. On the body whorl there are 5 spirals, 1 almost on the suture, the next 2 much more prominent. The median whorls each have 3 spirals, the 1st only 2. The basal fold is strong and fused to the columella. Aperture oval, relatively small and not oblique, the outer margin expanded and fortified externally by a strong but narrow tuberculate varix. Inner margin with a very slight sinus, but with a heavy, wide reflection over the columella. Length 5·4 mm.

Locality.—Darwin (J. Laseron), holotype.

Remarks.—This is a well-marked species with a slightly different protoconch from the preceding species and a different aperture. It can also be readily distinguished by the fewer spirals, and by the fact that these are stronger than the axials, making the margins of the whorls keeled.

PLANAPEXIA ELEVATA, sp. nov.

Fig. 59

Shell comparatively large, conical, elongate, solid, white, and translucent. Protoconch as in *P. quadrina*, a large nucleus immersed in a hollow summit within the revolution of the 1st mature whorl. Mature whorls 6, slightly rounded, restricted at the sutures. Sculpture regularly clathrate, axials and spirals nearly equal in strength, rising at their intersections into small, rounded gemmules. The axials number 20 to the whorl, the spirals 7 on the body whorl and 4 on each of the earlier whorls. The basal fold is strong, indented by the termination of the axial ribs. Aperture ovate, slightly oblique, outer margin not internally thickened, but with a wide external varix crossed by the continuation of the spiral ribs. Columella sinus deep, anteriorly situated, its margin widely reflected. Length of holotype 6·6 mm, of 1 paratype 7·3 mm.

Locality.—Darwin (J. Laseron), holotype and 3 paratypes.

Remarks.—This is easily the largest of the group, in its sculpture resembling *P. fractura*, but twice the size, with 2 more whorls, a narrower summit, and a slightly different protoconch.

Genus ISSELIA Schmeltz

Isselia Schmeltz, 1874, p. 110 (not *Isselia* Bourguignat, 1877).
Isseliella Weinkauff, 1884, p. 61, ex Nevill MS. (also spelt *Isselliella*).

Type species *Rissoina mirabilis* Dunker.

Schmeltz introduced this genus in the family Planaxidae, designating a type, but without further description. Nevill apparently changed the name for this reason, but without justification, for Bourguignat's *Isselia* lacks priority by 3 years. Nevill also designated a different type. Nevill's name was published by Weinkauff, who retained Schmeltz's original type. Later workers have erred in using *Stossichia* Brusina, 1870, for the group, as *Stossichia* is a Mediterranean Tertiary fossil with little resemblance to this group (Boettger 1887, 1893). Oliver at Iredale's suggestion used *Isselia* for Kermadec shells.

Isselia is a well-defined genus with a wide range over the Indo-Pacific regions, though most of the species seem to have a restricted geographical range. Previous descriptions have been brief, the main characters emphasized being small size, clathrate sculpture, sometimes rough, sometimes fine, stumpy form, mouth with prominent canal. The latter feature, the main characteristic, already referred to under *Fractoralla* as a pseudo-canal, needs further explanation. It is really a modification of the columella sinus, which is anteriorly situated and breaks right through the varix, forming a channel, bordered on one side by the truncate termination of a thick, bent columella column, and on the other by the abrupt termination of the interior thickening of the varix.

Among species from outside Australia, *Rissoina polytropa* Hedley from Funafuti has the typical *Isselia* aperture, but discrepant sculpture, a feature not noted in any Australian species.

ISSELIA POLYTROPA AUGEREA, subsp. nov.

Fig. 60

Rissoina polytropa Hedley, 1899, p. 420, fig. 12.

R. polytropa is now removed to *Isselia*. The type locality is Funafuti. As usual with Hedley's work the excellent figure and full description make identification comparatively easy. A number of specimens sorted from the Michaelmas Cay material agree almost exactly with the Funafuti species, except that on the body whorl the axial sculpture is well defined though fading on the base, whereas in typical *polytropa* the sculpture on the body whorl is of spirals only. This character is constant in all the specimens examined, and can be taken as racial, if not specific. Which is the parent form is open to doubt, but as Funafuti is a true oceanic island with an initial fauna presumably derived from elsewhere, it is probable that *polytropa* is a modification of *augerea* and is thus the subspecies. The length of *polytropa* is given by Hedley as 4·5 mm; that of *augerea* is 5 mm. In addition to the holotype 5 paratypes were selected.

ISSELIA LATERALIS, sp. nov.

Fig. 61

Shell of medium size, broad, with a convex spire, solid, white, and translucent. Protoconch of 1½ smooth, glassy whorls, the nucleus slightly tilted, the next whorl swollen and slightly larger than the apex of the spire, making it slightly mammilate. Mature whorls 5, rounded, restricted at the sutures, the penultimate whorl swollen, the body whorl large, nearly straight towards the base. Sculpture coarsely clathrate, the first post-nuclear whorl nearly smooth, thence the axials and spirals nearly equal, but on the body whorl the axials are stronger and then fade on the base. The axials number 16 to the whorl, the spirals about 12 on the body whorl and 5 on the penultimate. The intersections are marked by fairly prominent, rounded gemmules. Aperture ovate, oblique, thrust forward anteriorly, outer margin thick, varix wide and heavy, crossed by the spiral ribs. Columella in the form of a slightly curved, wide pillar, its inner margin covered with a heavy callus, anteriorly curved with a sharp edge bordering the pseudo-canal. Length 4·2 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype and 3 paratypes.

Remarks.—The coarse clathration at once distinguishes this from the other species here discussed.

ISSELIA UNDULATA, sp. nov.

Fig. 62

Shell small, broad, spire convex, white, and translucent. Protoconch large, of 1½ whorls, smooth and glassy, swollen. Mature whorls 4, rounded, restricted at the sutures, the penultimate whorl swollen, the body whorl large and curving evenly to the base. Sculpture of broad, rounded axial ribs, 12 to the whorl, and persisting to the base. These are crossed by spiral cords, close together, 7 on the penultimate and about 15 on the body whorl, but these are not coarse enough to produce a distinct clathration. Aperture broadly ovate, slightly oblique, outer margin with a wide external varix crossed by defined ridges, the thickened extensions of the spiral cords. Columella in the form of a wide, smooth pillar, slightly curved inwards, and terminally rounded to border the pseudo-canal, which is not so sharply defined on its opposite margin. Length 3·1 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype and 3 paratypes.

Remarks.—This is smaller than and has quite different sculpture from the species already discussed, besides differing in the number of whorls, in the larger protoconch, and in details of the aperture.

ISSELIA INCISA, sp. nov.

Fig. 63

Shell small, cylindro-conical, holotype fairly solid, white, and translucent, but 1 paratype thinner and nearly transparent. Protoconch large, nucleus slightly tilted, next whorl globose, sculpture beginning suddenly but faintly on the following whorl. Mature whorls 3½, rounded, restricted at the sutures, the penultimate whorl nearly as large as the body whorl, body whorl long, with an even curve to the base. Sculpture fine, predominantly of close, spiral cords, about 15 on the body whorl, 7 or 8 on the penultimate whorl. On the 1st whorl these are crossed by strong, close axial cords, making the sculpture finely clathrate, but on the body whorl the axials do not override the spirals but are confined to the spaces between and are altogether obsolete on the base. Aperture broadly ovate, oblique, outer margin expanded, not thick internally, the broad varix terminating abruptly anteriorly to form 1 margin of the well-defined pseudo-canal. The columella column is broad and bent inwards, with a sharp inner margin. Length 2·5 mm.

Locality.—Christmas I., holotype and 2 paratypes.

Remarks.—This delicately sculptured little species is quite distinct from other species of *Isselia* here discussed. It is smaller, has a thinner shell, finer sculpture, and a different shape, and differs also in the details of the aperture.

Genus MOERCHIELLA Nevill

Moerchiella Nevill, 1884, p. 73.

Type species *Rissoina gigantea* Deshayes (1863).

Nevill proposed *Moerchiella* for large rissoinids with the early whorls clathrately sculptured, the later ones spirally lirate only. He included a number of species from the Red Sea, the Andamans, Mauritius, the Philippines, and New Caledonia. Following Nevill, later authors have included under *Moerchiella* all large species with discrepant sculpture. In this wider sense the generic description needs amplification, as many species are not clathrate on the early whorls, but have axial ribs only, and the later whorls may be striate or quite smooth. Other characteristics are the rather thin shell, the absence of a varix, and the expanded aperture, which is very oblique, the anterior margin thrust forward like a scoop or shovel. A curious feature is that many species are liable to an irregularity of growth, producing distortion in the later whorls.

Melvill's *Chiliostigma refugiana* (1918, p. 147, pl. 5, fig. 20), described as a new subgenus and species from the Gulf of Oman, seems close to *Moerchiella*, having a large shell of similar form, but the sculpture is described as "close longitudinal striation with interstitial, close, spiral pitting". None of the Australian species comes here.

MOERCHIELLA EFFICATA (Brazier)

Figs. 64 and 65

Rissoina efficata Brazier, 1877, p. 366. Hedley, 1901, p. 127, pl. 17, fig. 26.

The type locality is the Barnard Is., Queensland, and the type in the Macleay Museum, first figured by Hedley, is 8 mm in length. This is evidently the same species as that recorded by Melvill and Standen (1899, p. 171) as *Rissoina thaumasia* Melvill & Standen from Torres Strait. The type locality of *thaumasia* is Madras. If these authors have correctly identified their own species, which is doubtful, *efficata* has priority and *thaumasia* becomes a synonym.

Figure 64 is of a specimen from Murray I. (C29511 in Australian Museum), slightly smaller than the type but otherwise close. Figure 65 is of one of a number of specimens from Michaelmas Cay; it is 7·8 mm in length and, if correctly identified, shows that the species is variable in the extent to which the spiral sculpture persists. Most of the Michaelmas Cay specimens have the last 2 whorls nearly smooth. The protoconch is short and naticoid, of $1\frac{1}{2}$ whorls, the nucleus large, sculpture beginning as a faint spiral keel, then axial ribs only for 1 or 2 whorls.

MOERCHIELLA ARTENSIS (Montrouzier)

Fig. 66

Rissoina artensis Montrouzier, 1872, p. 364.

The type locality is New Caledonia. Hedley identified and labelled specimens which he collected at the Annan River, Qld., as this species. That figured is from a series collected by J. Laseron at Thursday I. It is 13 mm long. Others are still larger, up to 16 mm in length, but it is otherwise constant, except that some specimens show the curious distortion of the later whorls often found in the genus. It is also common at Murray I. (Miss G. Thornley), and islands in the Torres Strait.

MOERCHIELLA PERSISTA, sp. nov.

Fig. 67

Shell of medium size, conical, slightly turreted, white. Protoconch of less than 1 whorl, nucleus large, immersed in the summit. Mature whorls 7, short, only slightly rounded, with a slight shelf below the sutures, particularly on the early whorls. Sculpture of axial ribs, 14–16 on the early whorls, where they are well defined and rounded, but much weaker on the penultimate, and practically obsolete on the body whorl, which is nearly smooth. Spiral sculpture absent. Aperture ovate, angled posteriorly, slightly oblique and thrust forward anteriorly, outer margin expanded and thin with a very slight external varix, columella bent backwards with a small shallow sinus. Length 6·2 mm.

Locality.—Thursday I. (J. Laseron), holotype and 2 paratypes.

Remarks.—This was easily separated from *M. artensis*, with which it was associated, by being less than half the size, by the greater persistence of the axial ribs, and by the less oblique aperture.

MOERCHIELLA DELETA, sp. nov.

Fig. 68

Shell of medium size, solid, conical, spire slightly convex, colour pale buff. Exact nature of protoconch not distinguishable, as the summit of the type is slightly worn. Mature whorls 7, short, not turreted, slightly rounded, sutures shallow. Sculpture of irregular, ill-defined axial ribs on the earlier whorls, becoming very faint on the later whorls, which are practically smooth except for some faint spiral threads. A weak varix is present on the penultimate whorl, suggesting a former complete aperture and a renewal of growth. Aperture ovate, angled posteriorly, only slightly oblique, the outer margin thickened internally and with a very slight external varix, columella with a shallow sinus. Length 8·6 mm.

Locality.—Port Curtis (J. Laseron), holotype.

Remarks.—This is close to *M. persista* in many characters, but it is a larger, broader, and more solid shell, with the axial sculpture weaker and less regular and persistent.

MOERCHIELLA VOLVERA, sp. nov.

Fig. 69

Shell large, thin, cylindro-conical, elongate, white. Protoconch small, of 2½ smooth whorls, sculpture beginning gradually on the 2nd whorl. Mature whorls 7, the first 4 short and turreted, the last 3 long and nearly equal in size. Sculpture of numerous axial ribs, well defined on the earlier whorls, where they number about 25 to the whorl, becoming weaker on the 3rd last whorl and only visible at the summit of the penultimate whorl. The body whorl is practically smooth, but there is a strong basal fold, and traces of the axial ribs can be seen in the deep, separating groove and on the edges of the fold itself. Aperture ovate, very oblique, sharply angled posteriorly, laterally and anteriorly well expanded, the outer margin thin with a wide but slight external varix, the columella with a shallow sinus. Length 10 mm.

Localities.—Annan River (C. Hedley), holotype; Lindeman I.; Murray I. (Miss G. Thornley).

Remarks.—While the sculpture, texture, and aperture all conform to *Moerchiella* as defined, the strong basal fold at once separates it from all the other species, and indeed suggests that the difference is generic rather than specific. The discovery of further species may later justify this step.

Genus DENTRISSOINA, gen. nov.

Type species *Dentrissoina thornleyana*, sp. nov.

A genus of the Rissoinidae resembling *Moerchiella* by having discrepant sculpture, but with a much shorter, broader, and heavier shell of few whorls, a strongly turreted spire, and the aperture with a heavy external varix and denticulate within.

DENTRISSOINA THORNLEYANA, sp. nov.

Figs. 70 and 71

Shell large, solid, broadly conical with turreted spire, white, and shining. Apex domed, the protoconch immersed in the summit. Mature whorls 5, the 1st domed, the next 2 turreted with concave sides, wider at the top than at the bottom, the body whorl large and inflated. Sculpture discrepant, the initial domed whorl and the following whorl with strong, raised, axial ribs with spiral threads between, the 3rd whorl nearly smooth, but its sharp upper rim indented by incipient axial ribs with faint spiral threads below. The penultimate and body whorls have spiral sculpture only in the form of numerous low, rounded cords, rather irregular but wider than the shallow channels between. Aperture large, pyriform, oblique and thrust forward anteriorly, outer margin thickened and fortified externally with a heavy, rounded varix, and bearing internally a number of narrow denticles. Inner margin swollen into a large basal fold over the columella, the peristome complete and attached to the body whorl. Length 8·5 mm.

Locality.—Murray I. (Miss G. Thornley), holotype (Fig. 70) and paratype (Fig. 71).

Remarks.—While not comparable with any Australian species, it is very close to the originally unique *Rissoa insignis* Reeve & Adåms (1850) from the China Coast, differing only in details of the sculpture and aperture. The species are undoubtedly congeneric.

Genus DIPSOTOMA, gen. nov.

Type species *Rissoa mercurialis* Watson.

Shell substance thin, vitreous, and translucent; whorls few, sometimes of very irregular growth and distorted, rounded; sculpture of fine spiral threads only; aperture large and laterally expanded, quite detached from the body whorl; varix not strong; columella sinus absent.

This is another of the odd Australian species which will not fit in any established genus. Hedley (1909) placed it in *Onoba* where it is equally out of place. The use of certain genera in a wide, ill-defined sense as a type of dumping ground for odd, discrepant species has in the past caused much confusion, and masked anything like a reasonable classification. It is far better that they be given generic as well as specific identity, so that future research into their relationship is untrammelled by a false nomenclature.

DIPSOTOMA MERCURIALIS (Watson)

Figs. 72–74

Rissoa mercurialis Watson, 1886, p. 600, pl. 45, fig. 12.

The type locality is Wednesday I. The specimens here figured are from Eagle I., collected by C. Hedley in 1916 (C41443 in Australian Museum). The length of the normal specimen (Figs. 72 and 73) is 5·5 mm and of the aberration (Fig. 74) 8 mm. In a long series from Michaelmas Cay most are rather smaller, averaging about 4 mm, and are thus nearer the type. Some also show the same curious aberrations, but not to the same degree as that figured. Under an ordinary lens the shell appears quite smooth, and it is only under a magnification of 10 or more that the fine spiral sculpture is revealed.

Genus ZYMALATA, gen. nov.

Type species *Zymalata concinna*, sp. nov.

Zymalata is proposed for a group of Australian rissoinids with large, laterally extended apertures, which are almost triangular in shape, with flattened outer and anterior margins, fortified with external varices which extend posteriorly above the normal suture some distance up the body whorl. From the back this gives the aperture a winged appearance. The columella sinus is at the anterior extremity, producing a marked angularity. The sculpture is similar to the Atlantic *Zebinella* Morch (1876, p. 47), of fine axial cords or narrow ribs, which may be closely packed or distant, and which become evanescent on the base. The spiral sculpture is of very fine cords or threads, generally closely packed and persistent to the base. The species are generally small and broad with swollen penultimate whorls.

ZYMALATA CONCINNA, sp. nov.

Fig. 75

Shell small, broad, spire slightly convex, texture relatively thin, white, and translucent. Protoconch large, of 3 smooth, glassy, short whorls, continuing the line of the spire, sculpture beginning gradually on the 3rd whorl. Mature whorls 4, rounded, restricted at the sutures, penultimate whorl swollen, body whorl large and sharply contracted at the base. Sculpture fine, axial cords first appearing, stronger and farther apart on the early whorls, diminishing to closely packed threads on the body whorl and evanescent on the base. The spiral sculpture is of closely packed threads, overriding the axials without marked beading, persistent to the base. Aperture large, triangular, very oblique and thrust forward anteriorly, outer margin expanded laterally, nearly straight, fortified with a heavy, wide varix, which is separated posteriorly from the body whorl by a narrow channel, and rising well above the suture. Anterior margin also nearly flat. Columella twisted backwards, the sinus reflected and open at its anterior end where the margin is sharply angled. Length 3·6 mm.

Locality.—Michaelmas Cay (T. Iredale), common, holotype and 6 paratypes selected.

Remarks.—This, the type species, is very distinctive, and there should be little difficulty in its future recognition. It is quite constant, the only variation being a slight difference in size, and also that a few specimens have the axial threads on the body whorl rather wider apart and coarser.

ZYMALATA TRIANGULARIS (Watson)

Fig. 76

Rissoina triangularis Watson, 1886, p. 618, pl. 46, fig. 7.

The type locality is Torres Strait. The specimen figured is from the Barrier Reef off Cairns (D. Pitt, C46090 in Australian Museum), and its length is 3·2 mm. The species is also very common at Michaelmas Cay. It is constant in its general characters, but varies slightly in size and width. That figured is slightly broader than the type figured by Watson. The species is very distinctive; the aperture is similar to that of *Z. concinna*, but the shell is smaller and broader and the sculpture is very different, the axials being few, only 12 to the whorl, and forming narrow but distinct ribs rather than cords.

ZYMALATA INERMIS (Brazier)

Figs. 77–79

Rissoina inermis Brazier, 1877, p. 367. Hedley, 1901, p. 127, pl. 5, fig. 28.

The type came from Darnley I. in Torres Strait and is in the Macleay Museum. Specimens here figured are from Michaelmas Cay (Fig. 77), length 5·4 mm, and from Murray I. (Figs. 78 and 79), length 5·8 mm. The length of the type given was 5·5 mm. A long series from Michaelmas Cay shows considerable variation both in size and relative width, but the essential characters are constant. The Murray I. specimens are narrower, as is shown by the figure, and specimens from southern Queensland are sometimes considerably larger than the typical form. The sculpture, shown magnified in Figure 79, is very finely clathrate.

In general characters *inermis* conforms to *Zymalata* as defined, though the aperture is not so triangular and the columella sinus does not break through to the anterior margin. It approaches nearer to the Atlantic genus *Zebinella* than the other species.

Genus CONDYLICIA, gen. nov.

Type species *Condylicia collaxis*, sp. nov.

This genus is proposed for the unique type species, which will not fit into any of the other groups here discussed. In some of its characters it resembles *Zymalata*, particularly in the fine sculpture, but the spiral sculpture consists of finely incised striae instead of raised threads. The texture is also different, being opaque and rather chalky. The aperture also has the outer and anterior margins rounded, making it semicircular and not triangular.

CONDYLICIA COLLAXIS, sp. nov.

Figs. 80 and 81

Shell small, solid, spire slightly concave, opaque, greyish white with a yellow summit. Protoconch large, cylindrical, of 2½ smooth whorls, the nucleus large, the next 2 whorls inflated and nearly equal, sculpture beginning gradually on the 3rd whorl. Mature whorls 4, rounded, restricted at the sutures, body whorl large and inflated. Axial sculpture of narrow but well-defined ribs, evanescent on the base, about 28 on the body whorl and 20 on the penultimate whorl. Spiral sculpture of fine, closely packed striae, not threads, between but not cutting the axial ribs, and more prominent on the base. Aperture large, semicircular, slightly oblique, well expanded laterally, outer margin fortified by a wide, smooth external varix, which rises posteriorly at the suture some distance up the body whorl. Outer and anterior margins rounded. Inner margin with a shallow sinus, anteriorly placed and reflected over the columella. Length 3·5 mm.

Locality.—No. 1, Howick Group (C. Hedley, 1916, C41445 in Australian Museum), holotype.

Remarks.—The unique holotype cannot be compared with any other species described in this paper.

Genus PYRAMIDELLOIDES Nevill

Pyramidelloides Nevill, 1884, p. 75.

Type species *Rissoina miranda* A. Adams.

Nevill included under *Pyramidelloides*: *Rissoina miranda* A. Adams from Hong Kong and Japan; *R. insolita* Deshayes from Mauritius, the Persian Gulf, Ceylon, and the Andamans; new subspecies *deformis*, *major*, and *depauperata* from Mauritius; and *R. bellardis* Issel, a subfossil from the Red Sea. Tryon (1887), who obviously could not have critically examined the material, wrongly synonymized all these under *R. miranda*. Later authors have been content to follow Tryon, recording any species of the genus from various localities including Torres Strait and New Caledonia as *miranda*, a sweeping generalization which is quite erroneous.

The genus is a well-defined and natural one. The shells are small, heavy, and conical to cylindrical in form, the spire often bent, the aperture oval with heavy varices. The sculpture is quite distinctive, with 2 strong, spiral keels on each whorl, the upper broken into large gemmules, the lower smaller and generally only partially tuberculate. In addition there are 1 or 2 plain keels surrounding the base.

A number of species exist, probably far more than at present realized, and though they approximate each other in sculpture they can usually be readily separated, particularly by the protoconchs, which are of very diverse types. As far as can be ascertained none of those previously described, including the type *miranda*, occurs in Australia, though the Australian species resemble, and in some cases are definitely identical with, those from New Caledonia.

PYRAMIDELLOIDES PACIFICA, sp. nov.

Fig. 82

Shell small, conical with bent spire, solid, white, and translucent. Protoconch globose, glassy, of 1½ whorls, terminating in a slight varix. Mature whorls 6, sutures deep. Sculpture of 2 prominent spiral keels on each whorl, the uppermost wide and broken into large oval gemmules, 16 to the whorl. These are connected by indistinct axial ridges across the intervening channel to the lower, narrower keel, which is only partially tuberculate. On the base of the body whorl are 2 additional plain keels. Aperture oval, not oblique, outer margin laterally expanded, externally with a narrow but prominent varix, inner margin thickened over the columella. Length 2·9 mm.

Localities.—Darwin (J. Laseron), holotype and 6 paratypes; Port Moresby, New Guinea (J. Laseron); Michaelmas Cay (T. Iredale).

Remarks.—This is evidently the species recorded by Watson (1886, p. 616) from Torres Strait, as *R. miranda* A. Adams. Specimens from New Caledonia are identical with *P. pacifica*, and these are probably the species known there as *Rissoina insolita* Deshayes. The true *insolita* was described from Reunion (Deshayes 1863, p. 63, Plate 13, Figs. 5 and 6) and has a straight and more slender spire and a finer apex.

PYRAMIDELLOIDES TURRIS, sp. nov.

Fig. 83

Shell small, elongate, spire with slight bend, white, and translucent. Protoconch conical, its base narrower than the summit of the mature shell, tapering to an acuminate apex, of 4 smooth, glassy whorls with flat sides, terminated by a varix. Mature whorls 6, of similar form and sculpture to *P. pacifica*, except that there are 3 plain spiral keels on the base instead of 2. Aperture oval, not oblique, surrounded by a heavy varix. Length 3 mm.

Locality.— 4–14 fm, Albany Passage (C. Hedley), holotype.

Remarks.—This species would be hardly distinguishable from *P. pacifica* were it not for the protoconch, which is of quite a different type. A number of additional specimens are in the Australian Museum from the type locality, mixed with *P. pacifica* and all labelled *Rissoina insolita*.

PYRAMIDELLOIDES CYLINDRICA, sp. nov.

Fig. 84

Shell small, nearly cylindrical, the spire with very little taper and practically straight, the apex blunt, white, and translucent. Protoconch large, planoid, of less than 1 whorl, fused in the summit. Mature whorls 5, sculpture practically the same as in the previous 2 species, except that the gemmules are irregular and not quite so large as shown in the drawing. There are 2 plain keels on the base. Aperture relatively small, oval, surrounded by a heavy, wide varix. Length 3·8 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype and 2 paratypes selected from a number of specimens.

Remarks.—This species can be distinguished from those already described by the larger shell and more cylindrical form, though again the protoconch is the deciding factor. This peculiar protoconch, the significance of which is unknown, has already been noted in other branches of the family, notably in *Planapexia*, where it has been made the chief generic character.

PYRAMIDELLOIDES VITICULA, sp. nov.

Fig. 85

Shell very small, conical, spire straight, vitreous, translucent. Protoconch large, conical, of 4 whorls, terminated by a varix. Mature whorls 4½, short, regular, sutures deep and narrow. Sculpture of 2 prominent spiral keels, the upper only slightly wider than the lower, the upper angled into the suture, both crossed by axial ribs, 16 to the whorl, and rising at the intersections into indefinite, elongated tubercles, the base with a single plain keel. Aperture oval, oblique and thrust forward anteriorly, outer margin sinuous posteriorly, not thickened but expanded outwardly into a broad, perfectly smooth varix, which is thickened and expanded over the inner margin. Length 2·7 mm.

Locality.—Christmas I., holotype and 1 paratype.

Remarks.—This beautiful little species, though conforming to the generic characters, is quite distinctive. The protoconch resembles that of *P. turris*, but it differs from this and the other species by the sculpture and details of the aperture.

Genus HEREWARDIA Iredale

Herewardia Iredale, 1955, p. 81.

Type species *Rissoina kesteveni* Hedley.

The unique type species certainly needed a new generic name, as there is no other group with which it can readily be compared. The salient features are the broad, squat form, the few whorls, and the turreted spire, each whorl having a broad shelf at the summit, above which the oblique axial ribs protrude. The obliquity of the ribs is in the opposite direction to those in such genera as *Pandalosia*, that is, they slant forward from below to the sutures. In addition to the axial ribs there are 2 strong spiral keels on the periphery of the body whorl and another on the base. The aperture is without a varix except for a slight thickening of the final axial rib.

HEREWARDIA KESTEVENI (Hedley)

Fig. 86 (after Hedley)

Rissoina kesteveni Hedley, 1907, p. 497, pl. 17, fig. 25.

The type locality is from 17 to 20 fm, off Mast Head I. in the Capricorn Group. The length given is 3·25 mm. It is evidently a rare species, perhaps confined to deeper water. The range, however, is fairly wide, as a specimen in the Australian Museum (C29519) is from Murray I. The unique features of the species have been outlined in the generic description.

Genus COSTABIETA, gen. nov.

Type species *Costabieta paucina*, sp. nov.

A genus having many of the features of *Herewardia*, a similar aperture with no defined varix, maturity being shown by a slight thickening of the final axial rib, and similar oblique axial ribs which slope forwards and upwards to the sutures. It differs in that it is conical in form and not turreted, the 2 spiral keels are not peripheral and persist on the earlier whorls, and the whole sculpture is broadly clathrate.

COSTABIETA PAUCINA, sp. nov.

Fig. 87

Shell small, regularly conical, white, and translucent. Protoconch large, short, a large nucleus, followed by half a swollen whorl, terminated by an indistinct varix. Mature whorls 4, sutures not deep. Sculpture of both axial ribs and spiral keels, the former 16 to the whorl, slightly oblique forward to the sutures, and rising above the keels in swellings rather than distinct gemmules. There are 2 keels on each whorl, a 3rd on the base of the body whorl, evenly spaced, the uppermost making a slight shelf just below the sutures. Aperture ovate, not oblique, not expanded laterally, outer margin thickened, an indistinct varix caused by the enlargement of the final axial rib, no sinus on the inner margin, which is, however, thickened into a wide basal fold. Length 2·7 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype and 2 paratypes.

Remarks.—There should be little difficulty in the future recognition of this species. From such species of *Phintorene* and *Planapexia* as superficially have similar sculpture it can be readily distinguished by the reverse obliquity of the axials, by the fewer spirals, and by the aperture.

Genus CONTRAXIALA, gen. nov.

Type species *Contraxiala obliqua*, sp. nov.

Shell small, very solid, broadly conical with channelled sutures and flat whorls, the sculpture of oblique axial ribs only, the ribs sloping forward and upwards to the sutures as in *Herewardia*. The aperture is oval, oblique, and without a varix.

CONTRAXIALA OBLIQUA, sp. nov.

Fig. 88

Shell small, very solid, broadly and regularly conical, white, and vitreous. Protoconch of a large, rounded nucleus immersed in the summit. Remaining whorls

4, increasing regularly, flat, body whorl large and inflated, sutures narrowly channelled. Sculpture of numerous fine, rounded, axial ribs, about 20 on the penultimate and about 26 on the body whorl, sinuous and oblique forwards and upwards to the sutures, where they thicken and form an ill-defined band, continuous below and curving into the base. Aperture oval, oblique, the peristome complete, thick, but without a varix. Length 2·5 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype.

Remarks.—This species has been proposed from a single specimen as its characters, both generic and specific, are so distinctive that its future identification should be without doubt.

Genus PELLAMORA Iredale

Pellamora Iredale, 1943, p. 206.

Type species *Iravadia australis* Hedley.

Pellamora is here used with some hesitation for a series of Australian shells, as the type was placed by Hedley in the Indian genus *Iravadia* Blanford. The basis of the separation by Iredale seems largely geographical, though he also states that the Australian shells are subcylindrical and of thinner texture and that he cannot see any close relationship. In the absence of Indian material for comparison it is impossible to verify if there is any real difference, but from the description of *Iravadia* (Blanford 1867, p. 56) the two are very close. *Iravadia* is reputed to be freshwater in habitat, and the type locality is the delta of the Irrawaddy River, but this may mean that it is really estuarine. Nevill (1884, p. 97) added *Rissoina trochlearis* Gould from the China Seas to the genus, and noted that this species was taken alive under stones at low tide, showing it to be truly marine. Hedley (1900) described *Iravadia australis* from "freshwater" at Bowen, but from the location it may well be estuarine or an inhabitant of the mangrove zone, as apparently it was not taken alive. Other allied Australian species here described are all beach specimens and their exact habitat is unknown. Some are unquestionably marine, notably those from Michaelmas Cay, an islet without fresh water and distant from the mainland.

The main characters of *Pellamora* are: subcylindrical to conical shells of moderately solid to thin texture, generally translucent, exserted aperture of rissoinid form, either variced or with the margins reflected outwards, sculpture of spiral ribs, the channels sometimes crossed diagonally by fine threads. There is also a brown periostracum which rapidly disappears after death, for only traces are sometimes found on beach specimens.

The true systematic position is still undetermined. Nevill described *Iravadia* as a subgenus of *Rissoina*, while Iredale placed *Pellamora* provisionally in a separate family Iravadidae. Until the animal and operculum are known this question must remain in abeyance. It is suggested that the group may be a branch of the Rissoinidae which is invading and adapting itself to brackish or even fresh water.

PELLAMORA AUSTRALIS (Hedley)

Figs. 89 (after Hedley) and 90

Iravadia australis Hedley, 1900, p. 727, pl. 48, fig. 12.
Syn. *Pellamora procera* Iredale, 1943, p. 206.

The type locality is "freshwater", Bowen, the length given being 5·3 mm. The type was decollate and had a brown periostracum. Iredale's *procera* was collected by J. Laseron from Darwin and was unfigured. The specimen here figured is from the same collection (Fig. 90) and is rather larger, 7·7 mm in length. Careful comparison does not show any other difference, and though the localities are distant it is considered that *procera* is the same species as *australis*.

PELLAMORA sp.

Figs. 91 and 92

Two shells, both collected by J. Laseron, one from Bowen, the other from Darwin, have sculpture and apertures identical with those of *P. australis*, but a peculiar feature in common which needs further material to understand. The Bowen specimen is figured and is 7 mm in length, that from Darwin is only 4·8 mm in length. *P. australis* as known has 4 mature whorls with an undetermined protoconch, each of these has only 3, and both at first sight appeared broken. Examination revealed, however, that the summits were entire, and that the initial whorl was conical and obtuse and folded within the apex, as shown in Figure 92, drawn with the shell slightly tilted. Whether this is the true protoconch or a plug filling the summit after the initial whorls were cast, as in *Truncatella*, the material is not sufficient to determine. If the latter, both specimens may be *P. australis*, and would indicate that species to be very variable in size and also in the number of whorls.

PELLAMORA LASERONI Iredale

Fig. 93

Pellamora laseroni Iredale, 1943, p. 206.

The type came from Darwin, and the brief description states that it is a small shell, 2·5 mm long, almost a miniature of *P. procera* (i.e. *australis*), the sculpture and form similar, 4 adult whorls, and a 1½ smooth, planate protoconch.

A specimen from the same collection as the type, made by J. Laseron, is now figured, and to the original description can be added the important facts that the aperture has no varix, but the rim is outwardly reflected, and that the texture is thin and translucent. This specimen is somewhat larger, 3·4 mm in length, but the size varies, and some mature specimens are smaller.

PELLAMORA REFLECTA, sp. nov.

Fig. 94

Shell small, subcylindrical, colourless, thin, and translucent. Protoconch short, a small planoid nucleus, followed by about one-half of an inflated whorl, terminated by a slight varix. Mature whorls 3½, rounded, restricted at the sutures, body whorl long. Sculpture of fine, elevated, spiral ribs, separated by about twice their width, 7 ribs on the penultimate and 12 on the body whorl. Axial sculpture of very fine oblique threads in the channels between the spiral ribs. Aperture ovate, laterally extended, the outer margin without a varix, thin and outwardly reflected, inner margin thin and reflected slightly over the columella. Length 2·9 mm.

Localities.—Darwin (J. Laseron), holotype and 6 paratypes; 4–14 fm, Albany Passage.

Remarks.—This is very close to *P. laseroni*, with which it is associated, and the two can be very easily confused. There are, however, several small but constant differences, the most important of which is the greater number of spiral ribs, 9 on the body whorl of *P. laseroni*, 12 on that of *P. reflecta.*

PELLAMORA ANGULATA, sp. nov.

Figs. 95 and 96

Shell of medium size, conical, turreted, white, and translucent, with a brown periostracum. Protoconch large, naticoid, smooth and glassy, of 1½ whorls, the nucleus smooth and planoid, the next whorl inflated, sculpture beginning gradually. Mature whorls 4, angulated at the shoulders, which bend in sharply to the sutures. Sculpture of fine, sharp, elevated spiral keels, separated by channels about 3 times their width, the topmost keel well below the suture. The keels number 3 on the 2nd whorl, 6 on the penultimate, and 9 on the body whorl. Numerous fine axial threads cross the channels between the spiral keels. Aperture oval, extended anteriorly, outer margin rounded and fortified with an external varix which persists anteriorly and over the inner margin. Length 5·5 mm.

Localities.—Darwin (J. Laseron), holotype; Karumba (C. Hedley), 6 specimens.

Remarks.—The angularity of the whorls easily distinguishes this from the other species discussed. The species seems very constant, and there is no difference between the Darwin and the Queensland specimens in spite of the distance between.

PELLAMORA DIMINUTA, sp. nov.

Figs. 97 and 98

Shell minute, cylindrical, colourless, thin, and translucent. Protoconch small, a medium-sized nucleus, and about one-half of a smooth whorl planoidly coiled on the summit. Mature whorls 4, the spire with very little taper, the last 3 whorls practically equal, separated by deep, wide sutures. Sculpture a few strong, rounded spiral ribs, less than their own width apart, 3 on each of the earlier whorls, 5 on the body whorl. Axial sculpture of very fine threads between the spiral ribs, only visible in certain lights. Aperture ovate, extended laterally, the outer, anterior, and inner margins thin and widely reflected. Length 2·3 mm.

Locality.—Darwin (J. Laseron), holotype.

Remarks.—This is a very distinctive little species, differing in size, form, and sculpture from all other species discussed.

PELLAMORA MINATURA, sp. nov.

Fig. 99

Shell minute, cylindrical with domed summit, solid, white, and translucent. Protoconch very large, the nucleus enclosed in the summit of a large, rounded whorl, on which sculpture gradually appears. Remaining whorls 2, nearly equal in size, rounded, slightly restricted at the sutures, the body whorl evenly rounded to the base. Sculpture of evenly spaced, rounded spiral ribs, separated by channels of about the same width, 7 on the first, 11 on the body whorl, the basal ribs larger than the others.

Aperture small, ovate, not oblique, laterally expanded, outer margin with a moderately heavy varix, inner margin reflected over the columella. Length 1·9 mm.

Locality.—Port Moresby, New Guinea (J. Laseron), holotype and 7 paratypes.

Remarks.—This is minute and cylindrical like *P. diminuta*, but has fewer whorls which are not so restricted at the sutures, the summit is broader, the sculpture is much finer, and the aperture is different.

PELLAMORA TRUNCATA, sp. nov.

Figs. 100 and 101

Shell small, very solid, broad, white, and translucent. The exact nature of the protoconch is uncertain. The holotype and all specimens examined have a truncate and hollow summit, in which is fused what appears as an irregular plug. This may be the protoconch, or a plug filling the summit after the true protoconch was cast. Mature whorls 3, the body whorl large and two-thirds of the total length, rounded, sutures deeply impressed. Sculpture of strong, rounded, spiral keels, 2 on the first, 4 on the second, and 6 on the body whorl. In addition the base is encircled by a very heavy fold, which is fused to but distinct from the varix on its inner margin. Under strong magnification fine axial threads are just discernible between the spiral ribs. Aperture large, oval, laterally and anteriorly extended, fortified by a heavy and wide varix. Length 3·3 mm.

Locality.—Darwin (J. Laseron), holotype and 13 paratypes.

Remarks.—This is the first of several species which diverge from the typical *Pellamora* by having broader, much more solid shells, with larger apertures, heavier and fewer spiral ribs, and heavier varices. One at least, and probably all have, however, a similar brown periostracum, and it is hard to find a line to justify further generic separation.

PELLAMORA CARPENTARIENSIS (Hedley)

Figs. 102–105

Rissoina carpentariensis Hedley, 1912, p. 139, pl. 42, fig. 20.

The type locality is Mornington I., Gulf of Carpentaria, the dimensions given being length 3·4 mm, breadth 2·1 mm. Figures 102 and 103 are of a specimen from 4–14 fm in Albany Passage (C. Hedley), its length being 3·5 mm. A still larger specimen from Mappoon (C14418 in the Australian Museum) is 4·3 mm long and has a deep brown periostracum. It was labelled *Iravadia* sp., and is now figured for comparison (Figs. 104 and 105).

The species is very close to *P. truncata*, but is narrower, with a different apex, there is an extra whorl, the aperture is not so large, and there is an additional spiral rib on the body whorl and a smaller basal fold. The protoconch is of about one-half a whorl, the nucleus within the summit, and terminated by a varix.

PELLAMORA CAPITATA, sp. nov.

Figs. 106 and 107

Shell very small, relatively narrow, solid, yellowish, and opaque. Protoconch large, of about 2 whorls, the nucleus planoid, the next whorl inflated, the 3rd terminated by an oblique varix. Mature whorls 2½, separated by deep sutures, the body whorl large and elongate. Sculpture of well-defined, rounded spiral ribs, separated by channels of about the same width, 6 on the penultimate, 10 on the body whorl, axial sculpture of fine, oblique threads barely discernible between the spiral ribs. Basal fold large, furrowed, formed by fusion of several of the lower ribs. Aperture large, subovate, oblique and thrust forward anteriorly, laterally and anteriorly extended, fortified by a heavy, wide varix. Length 2·6 mm.

Locality.— 4–14 fm, Albany Passage (C. Hedley), holotype.

Remarks.—This is smaller and has more spiral ribs than *truncata* and *carpentariensis*. In sculpture and aperture it approximates to *P. amplexa*, but again it is smaller, relatively narrower, and has a different protoconch.

PELLAMORA SPIRALIS, sp. nov.

Figs. 108 and 109

Shell small, broad with a truncate apex, fairly solid, white, and translucent. Apex nearly as in *P. truncata*, with what may be the protoconch or a small plug immersed within the hollow summit. Mature whorls 3, rounded, sutures constricted, body whorl large. Sculpture of regular, rounded, rather narrow spiral keels, 5 on the penultimate, 12 on the body whorl, of which the lowest is larger, approximating to the basal fold, which is otherwise absent. Axial sculpture very faint, of barely discernible threads between the spiral ribs. Aperture large and ovate, the outer margin not greatly thickened, but fortified externally with a wide but not heavy varix. Inner margin continuous, reflected over the columella, then partially hidden by the overhang of the body whorl. Length 2·5 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype.

Remarks.—This is about the same size as *P. capitata*, but is slightly broader, has more spiral ribs, and lacks the large basal fold; the aperture is also different, and it has a different protoconch.

PELLAMORA AMPLEXA, sp. nov.

Fig. 110

Shell small, broad, solid, apex blunt, white, and translucent. The apex is similar to that of *P. spiralis*, with what may be either an irregular plug or the protoconch immersed in the summit. Mature whorls 3, separated by deep sutures, rounded, the body whorl large. Sculpture of strong, rounded spiral keels, separated by channels about the same width, 3 commencing gradually on the 1st whorl, 5 on the 2nd, and 9 on the body whorl. No trace of axial sculpture could be detected. Basal fold very large, fused with and barely separate from the columella. Aperture large, oval, oblique and thrust forward anteriorly, laterally and anteriorly extended, fortified with a heavy, wide varix. Length 3·2 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype.

Remarks.—In form, size, and aperture this is close to *P. truncata*, but it differs chiefly in the greater number of spiral ribs. Compared with *P. spiralis* it is larger, the ribs are slightly fewer but much heavier, and the aperture is quite different.

Genus CHRYSTELLA, gen. nov.

Type species *Chrystella islandica*, sp. nov.

A genus resembling *Pellamora* in most characters, but differing by the development of the central spiral rib into a strong peripheral keel. Whorls short, with a strong basal fold, aperture oval, the outer margin outwardly reflected.

This is another strange little mollusc from Christmas I., whence so many striking novelties have come.

CHRYSTELLA ISLANDICA, sp. nov.

Fig. 111

Shell small, broadly conical, solid, white, and translucent. What may be the protoconch or merely a plug small, immersed in the summit. Mature whorls 4, wide at the periphery, restricted at the sutures. Sculpture of strong, rounded spiral ribs, 3 on the earlier whorls, the central rib larger and wider than the others and projecting as a prominent keel at the periphery. A 4th keel on the base of the body whorl, and a wide basal fold below this. Aperture oval, not oblique, extended laterally, outer margin thickened internally and externally reflected, but without a varix. Inner margin raised and slightly reflected. Length 1·5 mm.

Locality.—Christmas I., holotype.

Remarks.—The wide peripheral keel should make this species readily identifiable.

Genus LUCIDINELLA, gen. nov.

Type species *Lucidinella conicera*, sp. nov.

Small, subcylindrical shells, thin, of vitreous texture, body whorl with a strong basal fold, sculpture of fine spiral cords or threads, axial sculpture confined to minute threads, aperture semicircular, peristome complete, a varix sometimes present. The genus resembles *Pellamora*, but has a distinct facies, the texture is much thinner and the sculpture much finer, and the strong basal fold is very conspicuous.

LUCIDINELLA CONICERA, sp. nov.

Figs. 112 and 113

Shell small, subcylindrical, thin, vitreous, colourless, and translucent. Protoconch of a small planoid nucleus, followed by half an inflated whorl, terminated by a thin varix. Mature whorls 4, slightly shouldered below the sutures, penultimate whorl swollen. Sculpture of closely packed, spiral threads, crossed by even finer, slightly oblique, axial threads, a strong fold on the base of the body whorl. Aperture semicircular, posteriorly separated from the body whorl by a furrow, outer margin thin but expanded externally into a broad, longitudinally striated varix, inner margin thin and erect. Length 3 mm.

Locality.—Whitehaven Bay (J. Laseron), holotype and 2 paratypes.

Remarks.—This, the type of its genus, needs no comparison with other species, except that it differs from all species of *Pellamora* by the much thinner texture and finer sculpture.

Lucidinella conicera patruelis, subsp. nov.

Figs. 114 and 115

A series of small shells from Darwin, collected by J. Laseron, are so close to *L. conicera* that they are considered to be the same species, even though they differ slightly by being uniformly smaller, the holotype having a length of 2·2 mm, and by having a whorl less and very slightly coarser spiral threads. In view of the distance between Darwin and the type locality of *conicera* it is reasonable to expect racial divergence, and the Darwin specimens are therefore given an identity under a subspecific name. Traces of what appears to be a dark periostracum are visible on the holotype, emphasizing the probable relationship with *Pellamora*.

Lucidinella sublevis, sp. nov.

Fig. 116

Shell small, subcylindrical, colourless, thin, and translucent. Protoconch initially planoid, followed by a swollen whorl, no discernible varix, the almost invisible sculpture on the early whorls making it difficult to determine where the protoconch ends and mature growth begins. Remaining whorls 3, slightly rounded, only slightly restricted at the sutures, penultimate and body whorls long. Sculpture very fine, the surface under an ordinary lens appearing smooth, but with a magnification of 15–20, spiral threads are visible, closely packed and about their own width apart. No axial sculpture was detected. On the base is a wide fold, but not so prominent as in *L. conicera*. Aperture semicircular, laterally extended and posteriorly well separated from the body whorl. Outer margin thin with a faint but wide varix. Inner margin thin, erect, with a narrow cleft between it and the basal fold. Length 2·5 mm.

Locality.—Curtis I. (J. Laseron), holotype.

Remarks.—This can be readily separated from *L. conicera* by its smaller size, narrower form, more exsert aperture, and particularly the much finer, almost invisible sculpture.

Genus ZEBINA H. & A. Adams

Zebina H. & A. Adams, 1858, p. 328.

Type species, designated by Nevill (1884, p. 93), *Rissoina coronata* Recluz.

The original description reads: "Shell white, solid, opaque, polished, smooth or partially striated, outer lip thickened, often with one or more tubercles internally at the fore part". A number of species were included, and several of these, including the type species, were wrongly synonymized by Tryon (1887) under *tridentata* Michaud.

The description needs some amplification. The aperture is oblique and thrust forward anteriorly, the varix is well developed over the columella and is fused to the body whorl, and the whorls are flat with the sutures barely distinguishable. This feature and the smooth, polished surface give the genus a distinctive facies resembling some of the Eulimidae, with which of course it has no relationship. The protoconch, as with so many genera, is a useful feature for specific determination. Some of the species have a restricted range and there is very little individual variation.

ZEBINA HERONENSIS, sp. nov.

Fig. 117

Shell small, broadly conical, spire slightly convex, solid, white, polished, translucent. Protoconch short, glassy, of 1½ whorls, slightly tilted. Mature whorls 5, short, overlapping, sutures not impressed, the base of the previous whorl visible as a line well below the suture, the body whorl long. Sculpture of irregular, ill-defined axial ribs on the early whorls, the body whorl quite smooth and polished. Aperture ovate, laterally expanded, very oblique and thrust forward anteriorly, varix indistinct on the outer margin, but widening anteriorly and over the columella where it is fused onto the body whorl. Length 4 mm.

Locality.—Heron I., Capricorn Group (J. Laseron), holotype and 1 paratype.

Remarks.—Of the Australian species this is the only one with indistinct axial ribs on the early whorls, and in this character it approaches nearest to the type species *Z. coronata*, which comes from Mauritius.

ZEBINA TRIDENTATA (Michaud)

Fig. 118

Rissoina tridentata Michaud, 1830, p. 6.

The type locality is the Red Sea, and the species has also been recorded from Mauritius, the Philippines, New Caledonia, and the Sandwich Is. If all the identifications are correct the species has a very wide range in both the Indian and Pacific Oceans. The specimen figured is C29510 in the Australian Museum, collected by C. Hedley from Murray I., a large massive shell 10 mm in length. Another practically identical specimen is from Michaelmas Cay. That figured has 3 denticles within the aperture, that from Michaelmas Cay has only 2, but this seems a variable character developing only after full maturity. Of 2 otherwise identical specimens from Suvi Bay, Fiji, one may not be quite mature and has no denticles at all, the other has very faint traces of 3.

ZEBINA NITENS, sp. nov.

Figs. 119 and 120

Shell small, conical, white, highly polished, slightly translucent. Protoconch slightly mammilate and tilted, the nucleus large, the next whorl swollen, followed by a very short whorl, overlapped by the 1st mature whorl. Mature whorls 5, nearly flat, sutures barely visible, penultimate whorl slightly swollen, body whorl relatively long, curving regularly in to the base. Surface perfectly smooth and shining. Aperture ovate, expanded laterally, very oblique and thrust forward anteriorly, fortified with a heavy wide varix, continuing over the columella, where it is fused to the body whorl. Length 3·5 mm.

Locality.—Michaelmas Cay (T. Iredale), very abundant, holotype and 16 paratypes selected.

Remarks.—The general form and slightly mammilate protoconch should facilitate recognition. It greatly resembles some of the Eulimidae in general appearance, and but for the aperture might well be taken for one of that family.

ZEBINA HEBES, sp. nov.

Fig. 121

Shell small, solid, broadly conical, white, polished, and slightly translucent. Protoconch of less than 1 whorl, planoid, lying on the summit, giving the whole shell an obtuse apex. Mature whorls 5, nearly flat, sutures distinguishable but not indented. Surface smooth and shining. Aperture ovate, laterally expanded and very oblique as in *Z. nitens*, with a heavy varix widely extended over the columella. Length 3 mm.

Localities.—Port Moresby, New Guinea (J. Laseron), holotype and 4 paratypes; Rocky Is., Cape Flattery (C. Hedley); Barrier Reef off Cairns.

Remarks.—This resembles *Z. nitida*, but is broader and with a different protoconch. It also resembles in appearance some of the Eulimidae.

ZEBINA ISOLATA, sp. nov.

Fig. 122

Shell small, elongate, conical, white, shining, and translucent. The protoconch cannot be differentiated from the mature shell, but it has a large nucleus which is slightly tilted. Total number of whorls 7, nearly flat, the penultimate whorl slightly swollen, body whorl relatively short, curving in sharply to the base, sutures distinguishable but not indented. Surface smooth and polished. Aperture short, ovate, very oblique, outer margin sinuous, varix heavy and continued over the columella, where it is fused to the body whorl. Length 3·6 mm.

Locality.—Christmas I., holotype and 1 paratype.

Remarks.—This species is close to *Z. nitens*, having a similar but less mammilate protoconch, but it is more slender with an additional whorl, the body whorl is shorter with a different basal curve, and the aperture is also shorter.

ZEBINA ACICULA, sp. nov.

Figs. 123 and 124

Shell small, elongate, conical, acuminate, white, shining, and translucent. Protoconch small, acuminate, of about 2 whorls, indistinguishable from the mature shell. Total number of whorls including protoconch 9, flat, sutures faint and not indented, a line visible below them caused by the overlap of the whorls, body whorl fairly long and curved sharply in to the base. Surface smooth and polished. Aperture short, ovate, well expanded laterally, very oblique and thrust forward anteriorly, outer margin thin and sinuous, the varix developing anteriorly, and wide over the columella, where it is fused to the body whorl. Length 4·2 mm.

Locality.—Christmas I., holotype.

Remarks.—This is the narrowest of the species so far discussed, and its acuminate apex is a good recognition point.

ZEBINA LINEARIS, sp. nov.

Fig. 125

Shell small, elongate, cylindrical, white, and solid. Protoconch broadly conical, of 3 short whorls. Mature whorls 7, flat, sutures not indented and hardly distinguishable, body whorl with a slight even curve in to the base. Surface smooth. Aperture short, ovate, laterally expanded, very oblique and thrust forward anteriorly, the outer margin fortified with a heavy, wide varix, widening anteriorly and well developed over the columella. Length 3·3 mm.

Locality.—Christmas I., holotype.

Remarks.—This is an even more slender species than *Z. acicula* and has quite a different shape, the spire being almost cylindrical, the apex less acuminate, and the basal curve different. The varix also is more heavily developed on the outer margin.

ZEBINA CONSTRICTA, sp. nov.

Fig. 126

Shell small, elongate, conical, white. Protoconch indistinguishable from the mature shell, but the first 3½ whorls are more vitreous than the remainder though continuing the line of the spire. Total number of whorls 8, including the protoconch, rather long, the margins slightly rounded, and the sutures indented. Surface smooth. Aperture ovate, only slightly expanded laterally but well extended anteriorly, not so oblique as in the previous species, the outer margin with a heavy, wide, external varix, which extends well over the columella where it forms a solid pillar, separate and well forward from the body whorl. Length 3·5 mm.

Locality.—Christmas I., holotype.

Remarks.—This novelty is readily distinguished from all the other species by its rounded whorls and indented sutures, and it also differs in details of the aperture.

ZEBINA INFLATA, sp. nov.

Figs. 127 and 128

Shell large, solid, cylindro-conical, white, smooth, highly polished and translucent. Protoconch of less than 1 whorl, planoid, lying on the summit of the spire and giving it a blunt, domed appearance. Mature whorls 5, slightly rounded with sutures slightly impressed, the 1st 3 conical, the penultimate greatly swollen and as large as the body whorl. Aperture large, semicircular, very oblique, laterally greatly expanded, well thrust forward anteriorly, outer margin sinuous, varix not thick but very wide, thickening anteriorly and well developed over the columella, where it is smoothly fused with the body whorl. Columella with a slight, very shallow sinus. Length 8 mm.

Localities.—Rocky Is., Cape Flattery (C. Hedley, C41448 in Australian Museum), holotype and 1 paratype; Michaelmas Cay, common.

Remarks.—The irregular growth and greatly swollen penultimate whorl and the extreme lateral expansion of the aperture make this species very easy to recognize. These characters are remarkably constant in all of the many specimens examined.

Genus PALISADIA, gen. nov.

Type species *Palisadia subulata*, sp. nov.

A small shell with a cylindrical, elongated spire, subulate protoconch, sculpture of axial ribs which protrude above the sutures and are enlarged into prominent varices on either side, a basal fold surrounding the base. Aperture with complete peristome, subtriangular and distorted, surrounded by a strong varix, columella with a shallow sinus.

This extraordinary and unique little shell is of uncertain classification, but is placed provisionally in the Rissoinidae as the sculpture, the basal fold, and the aperture with a columella sinus suggest a relationship with that family. Search in the literature has failed to find anything with which it can be readily compared, but there is a possible link with a minute shell from "the China Seas", described as *Hoplopteron* by Fischer (1885, p. 784, text fig.). This has a similar subulate protoconch, and flattened spine-like varices on either side, but is without axial sculpture and has an oval aperture. Fischer placed *Hoplopteron* in the Eulimidae, but it is hard to see any relationship with that family.

Palisadia subulata, sp. nov.

Fig. 129

Shell small, cylindrical, solid, white. Protoconch subulate, smooth, long, and slender, of 4½ whorls, terminating abruptly. Mature whorls 4, slightly rounded, the penultimate as large as the body whorl. Sculpture of straight, narrow, sharp, closely placed axial ribs, which rise above the sutures in the form of a palisade. The ribs number about 24 to the whorl. In addition 2 prominent varices flank the spire, formed apparently by the fusion of 2 or more ribs, and rise high above the sutures as blunt spines. A strong spiral fold, indented by the termination of the ribs, encircles the base. Aperture subtrigonal, narrowed posteriorly, compressed medially, the anterior margin flattened, the margins fortified with a sharp, wide varix. Length 3·3 mm.

Locality.—Christmas I., holotype.

Remarks.—There is no other species nor indeed genus with which this can readily be compared.

Family RISSOIDAE

Key to the Australian Genera* of the Family Rissoidae

1.	Peristome complete	2
	Peristome incomplete	11
2(1).	Sculpture present	3
	Without sculpture	7
3(2).	Sculpture cancellate	4
	Sculpture weak axials and spirals, aperture detached	*Emblanda* Iredale
	Spiral sculpture only	5
4(3).	Sculpture heavy, regular, aperture oval	*Merelina* Iredale
	Sculpture discrepant, aperture round	*Discrevinia*, gen. nov.
5(3).	Solid and minute	6
	Thin and translucent, elongate, fine spirals	*Paradiala*, gen. nov.
6(5).	Fine spirals only	*Botelloides* Strand
	Two sharp keels, heavy varix	*Anabathron* Frauenfeld
7(2).	Minute and solid	8
	Shell thin and translucent	9

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* *Cyclonidea*, gen. nov., and *Nanadoma*, gen. nov., which are of uncertain classification, are not included in the key.

8(7).	Aperture round and reflected	*Estea* Iredale
	Aperture oval, spire finally uncoiled	*Saltatricula*, nom. nov.
	Inner margin flattened, spire short and inflated	*Scrobs* Watson
	Inner margin flattened, spire elongate, cylindrical	*Epigrus* Hedley
9(7).	Umbilicate, minute and inflated	*Lucidestea*, gen. nov.
	Not umbilicate	10
10(9).	Subcylindrical	*Mesodestea*, gen. nov.
	Conical, acuminate	*Mellitestea*, gen. nov.
11(1).	Sculpture present	12
	Without sculpture	*Vitricithna*, gen. nov.
12(11).	Sculpture cancellate	13
	Sculpture not cancellate	14
13(12).	Minute, broad, solid	*Haurakia* Iredale
	Larger, elongate, thin, sculpture often weak or discrepant	*Obtortio* Hedley
14(12).	Minute, solid, sculpture axial	*Parashiela*, gen. nov.
	Larger, thin, sculpture finely spiral	*Diala* A. Adams
	Larger, thicker texture, with varices	*Australaba*, gen. nov.

Genus MERELINA Iredale

Merelina Iredale, 1914, p. 449.

Type species *Rissoa cheilostoma* Tenison-Woods.

Merelina has been generally accepted to cover a number of species in southern temperate waters as well as in New Zealand, and its range can now be extended well into the tropics. Confusion between the two genera *Merelina* and *Haurakia* Iredale was discussed by Laseron (1950), but further study and experience since then should make the differences clearer. Iredale in his original diagnosis suggested the protoconch as the deciding factor: a striated protoconch in *Merelina*, a smooth one in *Haurakia*. This character, however, cuts right across other shell features, and the two groups fall out far better if the protoconch is here considered to have specific value only. From the type species the following shell differences may be summarized:

Merelina.—Peristome complete, aperture oval and often oblique with a heavy varix, sculpture strongly clathrate or tuberculate, the whorls often separated by deep channels.

Haurakia.—Peristome incomplete, aperture ovate, rarely with a varix, sculpture strong and semiclathrate, but the axial ribs generally fading on the base, which is spirally ribbed only.

Most species of both genera are very small or minute, but one Queensland species of *Merelina* attains a length of 4 mm. The few tropical species hitherto described have generally been placed under *Alvania*, a European genus, where they are quite out of place. None of the northern Australian species has been described, and a number fit well within *Merelina* as here understood, one coming very close to the type species, and another to the Peronian species *M. eminens* Laseron.

MERELINA QUEENSLANDICA, sp. nov.

Fig. 130

Shell minute, elongate, subcylindrical, solid, white, and translucent. Protoconch large, of 2 whorls, smooth, the nucleus fairly large, the next whorl swollen, terminated by a slight varix. Mature whorls 4, rounded, with deeply channelled sutures. Sculpture of strong, spiral ribs, broken into large, rounded tubercles by the axials, which are narrowed into bars in the channels between. The axials number 16 to the whorl, the spirals are 3 on the earlier whorls, with 2 smaller tuberculate ribs below these on the body whorl and a plain keel on the extreme base. Aperture nearly circular, relatively small, slightly forwardly oblique, outer and anterior margins extended, fortified with a heavy, wide varix. Length 2·1 mm.

Localities.—Barrier Reef off Cairns (A. R. McCulloch, C46226 in Australian Museum), holotype and 3 paratypes selected; Michaelmas Cay (T. Iredale), common; Bowen (J. Laseron), several specimens.

Remarks.—This is the narrowest of the Queensland species, and also the closest to the type species *M. cheilostoma*. It differs from the latter by having even more rugose sculpture and deeply channelled sutures, and by the more oblique aperture, which has the edge of the outer margin truncate.

MERELINA SOLIDA, sp. nov.

Fig. 131

Shell small, heavy, and solid, broadly conical, creamy white, opaque. Protoconch large, smooth, opaque, a small infolded nucleus, the next whorl inflated, sculpture first appearing gradually as 2 spiral ribs, followed by the axials. Mature whorls 4, nearly flat, sutures channelled but not deep, body whorl curving evenly to base. Sculpture of wide, flat spiral ribs, parted by narrow channels, and broken by the axials, which rise in regular, smooth, rounded gemmules, about their own width apart, and 16 to the whorl. The spirals number 3 of nearly equal size on the earlier whorls, 3 large and equal on the body whorl, with a thinner tuberculate rib below these, and 3 plain ribs on the base. Aperture oval, only slightly oblique, extended anteriorly, the outer margin thickened with an external, very heavy, wide varix. Length 3 mm.

Locality.—14 fm, Albany Passage (C. Hedley), holotype.

Remarks.—This is a distinctive species, much heavier, wider, and with less channelled sutures than *M. queenslandica*.

MERELINA SUCINA, sp. nov.

Figs. 132 and 133

Shell small, broadly conical, solid, translucent, the upper and basal rows of gemmules amber-coloured, remainder of shell white. Protoconch large, smooth, of 2 full whorls, the nucleus small and partially immersed, the next whorl short, the following whorl inflated and terminated by a thin, sharp varix. Mature whorls $3\frac{1}{2}$, slightly rounded, sutures channelled but not deep, body whorl regularly curved to the base. Sculpture of equal, narrow, raised spiral ribs, separated by wider channels, and broken by the axials into medium-sized, rounded gemmules, more defined on the upper row. The axials number 16–18 to the whorl, the spirals 3 on each of the earlier whorls and 4 on the body whorl, with a partially tuberculate rib on the base. Aperture oval, only slightly oblique, extended anteriorly but less so laterally, channelled posteriorly, outer margin very thick and fortified with a heavy, wide, smooth varix. Inner margin thick and reflected over the columella. Length 3 mm.

Locality.—Darwin (J. Laseron), holotype and 10 paratypes.

Remarks.—In form and general characters this is close to *M. solida*, but the sculpture differs in details, the spiral ribs are narrower, the gemmules are smaller, and the protoconch is different. The colouring should be a useful guide to future recognition.

MERELINA REVERSA, sp. nov.

Fig. 134

Shell small, broadly conical, solid, white. Protoconch large, nucleus infolded, followed by an inflated whorl, sculpture beginning gradually, first as spiral ribs followed by the axials. Mature whorls 3, sutures channelled but not deep, body whorl large. Sculpture of prominent spirals, narrow and well raised, about twice their width apart. Axials numerous, also narrow, slightly oblique forwards towards the sutures, rising above the spirals as small, rounded gemmules, larger on the upper row, which is just below the sutures. The axials vary in number, about 24 to the whorl on the holotype, but some specimens with as few as 20. The spirals number 3 on the earlier whorls, 5 tuberculate whorls on the body whorl, with 2 additional smooth ribs on the base. Aperture oval, reversely oblique, that is, receding anteriorly instead of being thrust forward, outer margin thick, with a heavy, wide, smooth external varix, inner margin narrowed and reflected over the columella. Length 2·8 mm.

Locality.—Bowen (J. Laseron), holotype and 7 paratypes.

Remarks.—A distinctive feature of this species is the reverse obliquity, opposite to that in most members of the genus, the axials sloping forward towards the sutures, and the aperture receding anteriorly. The axials, though variable in number, are always more numerous than in the species already discussed.

MERELINA HUMERA, sp. nov.

Fig. 135

Shell small, solid, broadly conical, white. Protoconch large, smooth, of $1\frac{1}{2}$ whorls, an infolded nucleus followed by an inflated whorl, sculpture beginning as faint spirals followed by the axials. Mature whorls 3, with long sloping shoulders above the topmost spiral rib to the sutures, which are impressed but not channelled, body whorl long. Sculpture of 2 prominent spiral ribs on each of the earlier whorls, 4 on the body whorl, the uppermost well below the suture, and an additional 2 or 3 small smooth ribs partially fused together on the base. The axials are strong, 18 to the whorl, rising above the spirals in rounded gemmules of moderate size. Aperture oval, oblique in the same reverse direction as in *M. reversa*, outer margin extended laterally, greatly thickened and fortified by a very heavy, wide varix, crossed by a continuation of the spiral ribs, inner margin thick and widely reflected over the columella. Length 2·8 mm.

Locality.—Darwin (J. Laseron), holotype.

Remarks.—This species has the same reverse obliquity observed in *M. reversa*, which it generally resembles, but it differs by the fewer axials, the narrower summit, and the long sloping shoulders of the whorls below the sutures.

MERELINA CORRUGA, sp. nov.

Fig. 136

Shell minute, solid, broadly conical, white. Protoconch small, a rounded nucleus immersed in the summit, sculpture beginning gradually on the 1st visible whorl. Mature whorls 4, increasing regularly, sutures channelled but not deeply, body whorl relatively short. Sculpture of 3 strong, spiral ribs on each of the earlier whorls, the uppermost bordering the suture, 4 nearly equal ribs on the body whorl, below which are 2 smaller, partially tuberculate ribs, and another smooth one on the base. The axials are strong and wide, 16 to the whorl, rising at the intersections into large, rounded gemmules. Aperture oval, oblique, thrust forward anteriorly in the manner normal to the group, outer margin with a heavy, wide varix crossed by the spirals, the inner margin wide and reflected over the columella. Length 1·9 mm.

Locality.—Heron I., Capricorn Group (J. Laseron), holotype and 4 paratypes.

Remarks.—This is the smallest of the northern species, and its nearest relation is probably the Peronian species *M. eminens* Laseron. Its very rugged sculpture is a good recognition point.

MERELINA GOLIATH, sp. nov.

Figs. 137 and 138

Shell large for the genus, conical, solid, yellowish white, some specimens deeper in colour, others white. Protoconch comparatively small, not quite perfect in the type, but with the whorls following the nucleus smooth and swollen, sculpture beginning gradually. Mature whorls 4, with shoulders sloping below the sutures, which are incised but not channelled. Sculpture of strong spiral ribs, 2 on each of the 1st 3 whorls, 4 on the body whorl, of which the uppermost is the strongest, and an additional, partially tuberculate rib on the base, which is separated from the aperture by a deep channel. The axials on the 1st whorl are fine threads between the spirals, becoming stronger and numbering 20 on the 2nd whorl, and 16 on each of the penultimate and body whorls. The intersections are marked by prominent, rounded gemmules, larger on the upper row, the interstices deep pits. The axials are continuous and strong on the shoulders above the uppermost spiral right to the suture. Aperture oval, with a slight reversed obliquity, outer margin thickened and fortified by a heavy, wide varix, which is crossed by the spirals and on which the axials are fine, crowded, and partially fused together. Inner margin reflected over a deep furrow. Length 4·6 mm.

Localities.—Hervey Bay (J. Laseron), holotype (Fig. 137) and 6 paratypes; Port Curtis (Museum specimen); Darwin (J. Laseron), abundant (Fig. 138); Sweers I. (C. Hedley).

Remarks.—This is by far the largest of the northern species. In general form it is nearest to *M. humera*, but differs in size and in details of the sculpture and aperture. In spite of the wide range there is very little variation, though the Darwin specimens are a little smaller, that figured being 4 mm in length.

MERELINA HIANS, sp. nov.

Fig. 139

Shell minute, solid, broadly conical, white, and translucent. Protoconch a large smooth nucleus on the summit of the 1st mature whorl. Remaining whorls 3, rounded, separated by deep channelled sutures. Sculpture clathrate, the axials and spirals about equal in prominence, rising into indistinct gemmules where they cross, the axials fading at the periphery of the body whorl. The axials number about 20 to the whorl; there are 4 spirals on the penultimate and 9 on the body whorl, the lower 5 of which are smooth. Aperture relatively very large, oval, upright, laterally and anteriorly widely extended, the outer margin with a narrow but very high varix. Length 1 mm.

Locality.—Christmas I., holotype.

Remarks.—This is the smallest of all the species studied, and the large and widely extended aperture also at once distinguishes it. The definable characters bring it within *Merelina*, but the great extension of the large aperture gives it a different facies, and the relationship may be more apparent than real.

Genus DISCREVINIA, gen. nov.

Type species *Discrevinia balba*, sp. nov.

A genus of small, solid shells related to *Merelina*, but elongate, with channelled sutures, aperture small and round, thickened but without a varix, sculpture discrepant. In the sculpture axials are predominant in the early whorls, spirals are few except on the body whorl.

DISCREVINIA BALBA, sp. nov.

Fig. 140

Shell minute, elongate-conical, spire slightly convex, white and translucent with a yellow apex. Protoconch smooth, of medium size, of 2½ whorls, the 1st whorl rounded, the next whorl short, no apparent varix. Mature whorls 5, at first increasing rapidly, but the penultimate nearly as large as the body whorl, nearly flat, the sutures channelled. Sculpture discrepant, at first wavy axial ribs crossed just above the suture by 1 slight spiral rib, with 2 spiral ribs on the penultimate whorl. The upper part of the body whorl is rendered clathrate by 3 spiral ribs, crossed by 14 short axial ribs which become obsolete on the periphery. Below this to the base are 6 additional smooth, rounded spiral ribs. Aperture small and nearly circular, extended anteriorly but not laterally, peristome complete, margins thick, external varix just discernible. Length 1·8 mm.

Locality.—Christmas I., holotype.

Remarks.—The sculpture and aperture easily separate this from any of the Australian species of *Merelina*, the only group with which it can be compared.

Genus HAURAKIA Iredale

Haurakia Iredale, 1914, p. 449.

Type species *Rissoa hamiltoni* Sutor.

The relationship of *Merelina* with *Haurakia* has already been discussed. Emphasis on the aperture as the main difference between the two genera is again made, *Merelina* having a complete peristome whereas in *Haurakia* it is incomplete, giving the aperture quite a different shape. The striated protoconch, used by Iredale to differentiate *Merelina*, can occur in both genera; though all the northern Australian species of *Merelina*, and all the species of *Haurakia* except one from Christmas I., have smooth protoconchs. The sculpture of *Haurakia* is strong and semiclathrate, the axial ribs stopping or fading on the base, where there are spirals only.

HAURAKIA NOVARENSIS TRAJECTUS (Watson)

Fig. 141

Rissoa trajectus Watson, 1886, p. 596, pl. 44, fig. 6.
Alvania novarensis Frauenfeld, 1867, p. 11, pl. 2, fig. 12. Hedley, 1907, p. 494.
Haurakia trajectus (Watson), J. Laseron, 1955, p. 77.

Alvania novarensis, a common Peronian species, was described by Frauenfeld (1867). It has also been recorded from Tasmania. Watson's *trajectus* was described from Torres Strait, and was later synonymized by Hedley under *novarensis*. J. Laseron (1955) considered it to be distinct and restored Watson's name. Long series from Keppel Bay and Port Curtis in Queensland and from Darwin, all collected by J. Laseron, have been carefully examined and compared, and the conclusion is now reached that there is no specific difference, and only a slight variation which can be put down to the long distance between localities and the change in environment between temperate and tropical seas. The variation, though slight, is constant; the northern form is slightly smaller, a little heavier, and the varix is also stronger. In other characters they are identical. By retaining *trajectus* as a geographical race it is possible that a true solution has been reached. The range of the species is therefore very great. The specimen figured came from Port Curtis, its length being 2·5 mm.

HAURAKIA FIRMA, sp. nov.

Fig. 142

Shell small, very solid, broadly conical, white, and translucent. Protoconch smooth, of 2½ whorls, of medium size, the last whorl relatively large, sculpture beginning gradually as axial ribs. Mature whorls 4, nearly flat, with channelled sutures. Sculpture strongly clathrate, both the axials and the spirals strong, rising at their intersections into small but well-raised, axially elongated bosses, the axials becoming weaker on the base. The axials number 16 to the whorl, the spirals 3–4 on each of the earlier whorls and 9 on the body whorl. Aperture ovate, upright, relatively small, not extended laterally, the outer margin channelled posteriorly, greatly thickened, externally with a strong varix. Peristome not complete, inner margin curved and reflected. Length 3 mm.

Localities.—Keppel Bay (J. Laseron), holotype and 20 paratypes; Port Curtis (J. Laseron), common.

Remarks.—This resembles *H. novarensis* in the number of axials, but the spirals are fewer, and both are much stronger and more rugged. The whole shell is also heavier, there is 1 whorl more, the whorls are flatter, and the sutures more deeply channelled. From the many specimens examined the species is very constant.

HAURAKIA FORMOSITA, sp. nov.

Fig. 143

Shell small, broadly conical, fairly solid, white, and translucent. Protoconch of medium size, smooth and glassy, of 2 whorls continuing the line of the spire, sculpture beginning gradually. Mature whorls 4, nearly flat, sutures marked by deep, narrow channels. Sculpture finely clathrate, the axials close and slightly stronger than the spirals, rising into small bosses where they cross, the axials fading on the base. The number of axials varies slightly; on the holotype there are about 24 to the whorl, on some specimens as few as 20. The spirals are numerous and narrow, 4–6 on the earlier whorls and 13–14 on the body whorl. On the base, where there are no axials, the spirals are broad and separated by narrow furrows. Aperture broadly ovate, slightly oblique and thrust forward anteriorly, outer margin narrowly channelled posteriorly, rounded, not thickened, but with a broad exterior varix, inner margin curved, reflected over the columella, peristome not complete. Length 3 mm.

Locality.—Michaelmas Cay (T. Iredale), common, holotype and 10 paratypes selected.

Remarks.—In form this resembles *H. firma*, but it is altogether a lighter shell, and the sculpture is much finer than in either *H. firma* or *H. novarensis.*

HAURAKIA ISOLATA, sp. nov.

Fig. 144

Shell minute, broadly conical, white with irregular brown patches below the suture and on the base. Protoconch relatively large, of slightly more than 1 inflated whorl, finely and spirally lirate, terminated by a slight varix. Mature whorls 3, increasing rapidly, rounded, sutures deep but not channelled. Sculpture strongly clathrate, the axials strongest, but fading on the base, the intersections marked by rounded gemmules. The axials number 16 to the whorl, the spirals 3 and 4 respectively on the earlier whorls and 9 on the body whorl. As the axials fade the spirals become stronger, and on the base they are wide and separated by about their own width. Aperture broadly ovate, upright, outer margin with a slight channel posteriorly, curved, thin, outwardly slightly reflected but without a varix, inner margin curved and narrowly reflected, peristome incomplete. Length 1·5 mm.

Locality.—Christmas I., holotype and 10 paratypes.

Remarks.—The sculptured protoconch at once separates this from the northern Australian species, conforming to what was originally considered the chief characteristic of *Merelina*, though the other shell characters are those of *Haurakia.*

Genus PARASHIELA, sp. nov.

Type species *Parashiela ambulata*, sp. nov.

A genus of the Rissoidae resembling *Haurakia* by the short, broad shell and rather thin texture, but with a complete peristome and different sculpture. This consists of thin axial ribs curving into the base and crossed at the shoulder by a thin, spiral rib. The aperture is very exsert, rounded, without a varix, the margin thin and outwardly reflected.

PARASHIELA AMBULATA, sp. nov.

Fig. 145

Shell minute, broadly conical, moderately solid, white, and translucent. Protoconch relatively large, smooth, of 2 whorls, the nucleus small, the 2nd whorl much larger than the 1st, sculpture beginning gradually. Mature whorls 3, sharply angled at the shoulders, with a sloping terrace below the sutures. Sculpture of narrow, sharply defined, distant, straight axial ribs, continuous from the suture and curving in to the base. These are crossed at the shoulder by a single, narrow, sharply defined spiral rib. The axials vary in number; on the holotype there are 14 on the body whorl and about 16 on the penultimate whorl, but in some specimens they are more numerous, in others as few as 12 to the whorl. Aperture round, well extended both laterally and anteriorly, the peristome complete but its inner margin hidden from in front by the overhang of the body whorl, margins thin, without a varix, but widely reflected all round. Length 1·6 mm.

Locality.—Michaelmas Cay (T. Iredale), common, holotype and 10 paratypes selected.

Remarks.—The very distinctive sculpture should make the future recognition of this species easy.

Genus BOTELLOIDES Strand

Botelloides Strand, 1928, nom. nov. for *Botellus* Iredale, 1924, p. 244 (preocc.).

Type species *Onoba bassiana* Hedley, 1911, p. 108, pl. 19, fig. 25.

Small shells of few whorls, very solid, ovoid in outline, body whorls more than half the total length, apertures rounded, peristomes complete, the margins thick with truncate edges, sculpture of fine spiral cords. In addition to the type species, which is a Tasmanian deep-water shell, Iredale included the Queensland species *Onoba glomerosa* Hedley, but no further species have since been discovered.

BOTELLOIDES GLOMEROSA (Hedley)

Fig. 146 (after Hedley)

Onoba glomerosa Hedley, 1907, p. 495, pl. 17, fig. 23.

The type locality is 17–20 fm, Mast Head I., Capricorn Group, where Hedley states it to be common. The length is given as 2·9 mm, the colour as milk white to pale ochre, yellow at the summit. Hedley's excellent figure and full description leave little to be added.

Genus ESTEA Iredale

Estea Iredale, 1914, p. 451.

Type species *Rissoa zosteophila* Webster.

The main characters are the small, solid, few-whorled shell, with a circular aperture and complete peristome, the margin of which is outwardly reflected all round. Later authors, including Hedley, May, Cotton, Powell, and Laseron, have taken this definition to include sculptured as well as smooth shells, but Iredale (1955, p. 81) has proposed *Feldestea*, type species *Rissoa salebrosa* Frauenfeld, for species with axial sculpture, and *Nodulestea*, type species *Estea castella* Laseron, for those with nodulose sculpture, thus restricting *Estea* proper to the smooth forms. The genus in its distribution belongs essentially to southern temperate waters, and it is rare in the tropics. The few species are here referred to it with some doubt, and it may be necessary later to review their systematic position.

ESTEA LUNATA, sp. nov.

Fig. 147

Shell minute, regularly conical, texture porcellanous and opaque, thin, white with large, amber-coloured patches on the upper part of the whorls, the base pale amber and a row of crescent-shaped amber patches on the periphery. Protoconch a small nucleus just visible centrally above the rim of the apex. Remaining whorls 4, slightly rounded, sutures not deeply impressed, body whorl large. Sculpture absent, the surface smooth and polished. Aperture round, peristome entire, just visible on the inner margin, slightly outwardly reflected all round. Length 1·8 mm.

Locality.—Bowen (J. Laseron), abundant living on algae, holotype and about 30 paratypes.

Remarks.—The colour pattern of this species should make its future recognition easy. The texture is rather thinner than normal, and the aperture is less reflected than in most species of the genus.

ESTEA PERDIGNA, sp. nov.

Fig. 148

Shell small, solid, conical, spire slightly convex, opaque, colour yellow-brown with occasional darker streaks axially disposed. Protoconch minute, a small nucleus just visible on the rounded summit. Remaining whorls 5, slightly restricted at the sutures, the penultimate whorl swollen. Sculpture absent. Aperture round, upright, the peristome complete and slightly outwardly reflected all round. Length 2·4 mm.

Locality.— 17–20 fm, Mast Head I., Capricorn Group (C. Hedley), holotype and 7 paratypes sorted from a full tube of specimens, most of which have partially disintegrated.

Remarks.—This is a true *Estea*, approximating in colour, form, and texture to the Peronian members of the genus. Of these *E. tasmanica* Tenison-Woods is the nearest in form.

ESTEA EURYCHADES (Watson)

Fig. 149 (after Watson)

Eulima eurychades Watson, 1886, p. 522, pl. 37, fig. 7.

The type locality is 155 fm, off Raine I., Cape York, and the length given is 0·119 in. or approximately 2·9 mm. The shell is solid, the texture polished, and the colour white with smoky bands. This deep-water species has not been rediscovered, but Watson's figure and description should make its recognition easy.

It is almost certainly an *Estea*, though Watson doubtfully placed it in *Eulima*. His opinion on this point is well worth quoting as it expresses so well contemporary views on the status of genera: "This is certainly a very aberrant species of *Eulima*, and, but for the *foolishness of such sub-divisions*, might form the basis of a new genus".

ESTEA XANTHIAS (Watson)

Fig. 150 (after Watson)

Mucronalia xanthias Watson, 1886, p. 523, pl. 37, fig. 8.

The type locality is 18 fm off Tongatabu (between Fiji and New Caledonia), and the author also records it from 8 fm off Wednesday I. in Torres Strait, the length given being 0·049 in. or approximately 1·2 mm. The colour is given as white with a yellow tip, and the texture as microscopically striate. This is another species which has not been seen since its original discovery. It is certainly not a *Mucronalia*, and the round aperture with its reflected margin is that of *Estĕa*, though the texture suggests other relationship. Until further material comes to hand this question is left in abeyance.

Genus SCROBS Watson

Scrobs Watson, 1886, p. 611.

Type species *Rissoa* (*Scrobs*) *scrobiculatus* Watson.

Though proposed as a subgenus, *Scrobs* has since received general acceptance as a full genus. The shell is minute, very solid, smooth, few whorls, the body whorl large and swollen, the peristome complete with no varix, the aperture flattened on the inner margin and separated from the body whorl by a channel, which may be reduced to a mere slit, as in the type, or quite wide.

Iredale (1955, p. 81) proposed a further subdivision, separating species with a wide channel between the aperture and the body whorl as *Obescrobs*, type species *Rissoa jacksoni* Brazier, and *Ultiscrobs* with *Scrobs pluteus* Laseron as type. Both types are Peronian species. In the latter unique species the peristome is broken on the inner margin and replaced by a shelf deep within the aperture. This distinctive character may well merit generic separation, but the broad channel of *S. jacksoni* is a character of degree more than kind, and is doubtfully of more than specific value. At the other extreme one of the species described here, *S. incipiens*, has the inner margin reduced to a band of callus on the body whorl, but again this is considered a stage only in the development of one character, and is not given generic value.

SCROBS TROPICA, sp. nov.

Fig. 151

Shell minute, subcylindrical, solid, slightly translucent, yellow-brown, with a white band below the periphery and white spots on the base, the band spreading irregularly on the back of the body whorl, which is quite white at the aperture. Many specimens other than the holotype are uniformly brown in front, but all show the white coloration on the back. Protoconch a small nucleus in the summit, not differentiated from the mature shell. Remaining whorls 4, sutures only slightly impressed, the penultimate whorl large and swollen, the body whorl also swollen. Aperture sublunate, the inner margin flattened, the peristome entire, separated by a narrow channel from the body whorl, outer margin extended laterally, anterior and inner margins slightly reflected. Length 1·2 mm.

Locality.—Heron I., Capricorn Group (J. Laseron), alive under coral blocks, holotype and about 50 paratypes.

Remarks.—This is close to the type species *S. scrobiculatus* from the Peronian Province but differs in contour, and can easily be distinguished by the colouring.

SCROBS COMPRESSA, sp. nov.

Fig. 152

Shell minute, broadly conical, fairly solid, slightly translucent, yellow-brown with a paler band just above the periphery. Protoconch small, the initial whorl coiled on the summit, not differentiated from the mature shell. Remaining whorls 4, slightly rounded, sutures not deeply impressed, body whorl large. Sculpture absent, surface shining. Aperture nearly oval, but slightly straightened on the inner margin, slightly oblique, extended anteriorly but not laterally, bringing it below the centre of the spire, peristome entire, separated from the body whorl by a narrow channel, outer margin thin, not reflected, inner margin slightly reflected over the columella. Length 1·6 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype and 6 paratypes.

Remarks.—This closely resembles *S. tropica*, having a similar texture and nearly the same colour pattern, and at first sight they might be taken as the same species, but comparison, side by side beneath the microscope, shows distinct differences. *S. compressa* is about one-third larger, is slightly more slender and has a conical rather than a subcylindrical spire, and the aperture is not laterally extended, but is nearly below the centre of the spire.

SCROBS INCIPIENS, sp. nov.

Fig. 153

Shell minute, ovate, broad and tumid, solid and opaque, a broad yellow-brown band on the periphery of the body whorl and the lower half of the penultimate whorl, the whorls above yellow-brown, the apex and remainder a dull yellow-white. Whorls 4, the 1st dome shaped with a minute nucleus in the summit, penultimate and body whorls swollen, sutures shallow. Surface smooth. Aperture nearly round, extended anteriorly and nearly below the centre of the spire, peristome just complete, the inner margin reduced to a thin band of callus on the body whorl, the other margins widely reflected all round. Length 1·6 mm.

Locality.—Heron I., Capricorn Group (J. Laseron), alive under coral blocks, holotype and 6 paratypes.

Remarks.—The features of the aperture at once separate this from all other species of *Scrobs*. The barely complete peristome indeed suggests generic separation, but again it is considered that this is of degree rather than kind, the beginning of a development which in its next stage is the typical *Scrobs*, proceeding to species in which the aperture becomes more and more separated from the body whorl. Apart from this all the species have a similar facies and, as far as is known, habitat, and constitute a natural genus.

SCROBS FULCIRA, sp. nov.

Figs. 154 and 155

Shell exceedingly minute, broadly conical, solid, opaque, amber-coloured, white on the base and around the aperture. Whorls 3, the 1st dome shaped with a minute nucleus within the summit, the penultimate whorl not swollen, body whorl very large and inflated. Sculpture absent, the surface shining. Aperture quite free, nearly oval, the inner margin only slightly flattened, with a wide channel between it and the body whorl, this channel closed posteriorly by a narrow partition connecting the peristome to the body whorl. Outer margin extended and slightly reflected, both laterally and anteriorly. Operculum thin, horny, paucispiral, the nucleus submarginal. Length 0·8 mm.

Locality.—Lindeman I., common in weed washings, holotype and about 20 paratypes.

Remarks.—This is not only the smallest of the group here discussed, but represents the development of the aperture beyond the typical *Scrobs*. If Iredale's *Obescrobs* be accepted, it would come within it, though the aperture is not so widely separated as in the type species.

SCROBS OBLATA, sp. nov.

Fig. 156

Shell minute, ovoid in contour, pale yellow, solid, vitreous, and translucent. Protoconch minute on the domed summit of the 1st mature whorl. Whorls 3, the 1st relatively small, the last 2 equal in diameter, but the body whorl long, sides nearly flat, sutures barely impressed. Sculpture none, surface shining. Aperture semicircular, outer margin outwardly expanded and rising posteriorly above the suture, inner margin adhering to the body whorl, curved on the outer edge, but forming a flat surface and terminating in a straight line well within the aperture. Length 1·5 mm.

Locality.—The holotype was sorted by T. Iredale from shell sand collected by Mrs. B. Page from Noosa Head, southern Queensland.

Remarks.—Once again the aperture is the most useful guide to recognition. In its progressive change from species to species, *S. oblata* represents the stage between *S. incipiens* and *S. tropica* in which the aperture has not yet become entirely detached from the body whorl.

Genus ANABATHRON Frauenfeld

Anabathron Frauenfeld, 1867, p. 13.

Type species *Anabathron contabulatum* Frauenfeld.

A curious genus of minute shells, very heavy and solid, brown or red in colour, the whorls sharply angled at the periphery by 2 spiral keels, peristome complete, the aperture round with a heavy flat varix. In the type species the varix is fused to the body whorl, but in one Queensland species the aperture is quite free.

The only species so far known are 2 from the Peronian Province and 2 described by Hedley from Queensland.

ANABATHRON ASCENSUM Hedley

Fig. 157 (after Hedley)

Anabathron ascensum Hedley, 1907, p. 496, pl. 17, fig. 20.

The type came from 17 to 20 fm, Mast Head I., Capricorn Group, the length given by Hedley being 1·95 mm. Hedley's excellent figure and full description leave nothing to be added, and there should be no difficulty in the recognition of this striking little shell.

ANABATHRON CONTORTUM Hedley

Fig. 158 (after Hedley)

Anabathron contortum Hedley, 1907, p. 496, pl. 17, fig. 21.

The type came from 17 to 20 fm, Mast Head I., the length given being 1·24 mm. The uncoiling of the body whorl separates this from all the other known species, and suggests that here is a development of the aperture parallelling that in *Scrobs*.

ANABATHRON LENE Hedley

Fig. 159

Anabathron contabulatum var. Frauenfeld, 1867, p. 13, pl. 2, fig. 20*b*.
Anabathron contabulatum lene Hedley, 1917, p. 53.
Anabathron lene Hedley, Laseron 1950, p. 275.

The specimen here figured came from shell sand, Noosa Head, collected by Mrs. B. Page. Its length is 1 mm. The species has been fully discussed in the author's previous (1950) paper, and it is quite common in the Peronian Province. The Noosa Head specimen is not only a new record for the Solanderian Province, but is additional evidence that the species is constant throughout its distribution and quite distinct from *A. contabulatum*, of which both Hedley and Frauenfeld considered it but a subspecies.

Genus EMBLANDA Iredale

Emblanda Iredale, 1955, p. 81.

Type species *Rissoa emblematica* Hedley.

A minute genus of the Rissoidae differing from *Anabathron* by the presence of axial sculpture as well as spiral ribs. The whorls are few, the protoconch very large, and the aperture is quite detached and oval in form.

Hedley (1917, p. 53) transferred the type to *Anabathron*, a course followed by Laseron (1950, p. 276). By proposing a new genus for its reception Iredale has now removed a discordant element from the otherwise compact and natural *Anabathron*. It is suggested that *Emblanda* is probably nearer *Merelina* in systematic classification.

EMBLANDA EMBLEMATICA (Hedley)

Fig. 160

Rissoa emblematica Hedley, 1905, p. 526, pl. 32, fig. 24.

A single, slightly worn specimen from shell sand from Noosa Head, collected by Mrs. B. Page, is clearly identifiable and adds a new record from the Solanderian Province. Its length is 1·8 mm. Noosa Head is just within the boundaries of the Solanderian Province, and occasional records of Peronian species can be expected from this locality.

Genus SALTATRICULA, nom. nov.

Saltatricula, nom. nov. for *Saltatrix* Laseron, 1950, p. 277, preocc. by *Saltatrix* King, 1834.

Type species *Epigrus protractus* Hedley.

Minute, solid, cylindrical shells of few whorls, without sculpture, with oval apertures, the spire becoming quite uncoiled in the latter stage of growth, straightening and with the aperture opening obliquely downwards. The texture of the shell and form of the aperture suggest a relationship with *Scrobs*, from which it chiefly differs by the narrower, elongate, and cylindrical spire.

SALTATRICULA PROTRACTUS (Hedley)

Fig. 161

Epigrus protractus Hedley, 1904, p. 185, pl. 8, figs. 8–11.

Two specimens of this curious little shell were sorted by T. Iredale from shell sand collected by Mrs. B. Page from Noosa Head, a new record from the Solanderian Province. That figured is 1·2 mm in length. It exactly matches typical specimens from the Peronian Province.

SALTATRICULA BALLERINA, sp. nov.

Fig. 162

Shell minute, cylindrical, solid, yellowish, and opaque. Protoconch of about 1 whorl, coiled on the summit. Remaining whorls 3, of nearly equal diameter, the 1st short and inflated, the next about twice the length with rounded margins, the body whorl still longer and finally completely uncoiled, straightening downwards in the line of the spire, sutures not deeply impressed. Aperture oval, evenly rounded, downwardly oblique, the margins even and truncate all round. Length 1·2 mm.

Locality.—Whitehaven Bay (J. Laseron), holotype.

Remarks.—This is close to *S. protractus*, but compared under the microscope it is seen to be altogether a more solid and broader shell. The uncoiled portion is also not quite so long, and the apex is slightly different.

SALTATRICULA STRINGERA, sp. nov.

Fig. 163

Shell minute, subcylindrical, solid, yellow-brown, and slightly translucent. Protoconch a large nucleus on the broad summit of the 1st mature whorl. Mature whorls 3, increasing gradually and not subequal in diameter as in other species, the 1st short, the body whorl more than half the total length, all whorls rounded and restricted at the sutures, the body whorl finally uncoiled and straightening anteriorly. Sculpture absent. Aperture oval, downwardly oblique, the inner margin flattened, the margins evenly slightly reflected all round. Length 1·5 mm.

Locality.—Holotype and 1 paratype sorted by T. Iredale from shell sand from Noosa Head collected by Mrs. B. Page.

Remarks.—This is slightly larger than the other species, and can also be readily distinguished by the less cylindrical spire, the inflated body whorl, and the restricted sutures.

SALTATRICULA IMPRORSA, sp. nov.

Fig. 164

Shell minute, cylindrical, solid, bright golden brown, translucent. Protoconch very small, coiled on the summit. Remaining whorls 4, the last 3 very nearly equal in diameter, the 1st whorl globose, the next 2 nearly equal in length, the body whorl long, all slightly rounded with sutures slightly restricted. Body whorl finally uncoiled, but the uncoiled portion not long, and not straightened anteriorly. Sculpture none. Aperture oval, hardly downwardly oblique, inner margin flattened, outer margin slightly thickened but not reflected. Length 1·4 mm.

Locality.—Holotype and 2 paratypes sorted by T. Iredale from shell sand collected by Mrs. B. Page from Noosa Head.

Remarks.—This can be readily distinguished from all the other species by the extra whorl and by the shorter uncoiled portion of the body whorl.

Genus NANADOMA, gen. nov.

Type species *Nanadoma imitoris*, sp. nov.

A minute shell with a similar aperture to *Epigrus*, but broader and more cylindrical in form, with fewer whorls, a large broad apex, and a different texture. The texture is very thin and translucent, the surface is not polished, and faint growth lines are visible. Though the general form resembles *Epigrus*, the differences are such as to give it quite a different facies, and there is probably little relationship.

NANADOMA IMITORIS, sp. nov.

Fig. 165

Shell minute, cylindrical, colourless, thin, and translucent. Protoconch of about 1 whorl, flatly coiled upon the apex. Remaining whorls 3, practically equal in diameter, the 1st rounded and inflated, the next longer and slightly rounded, the body whorl slightly more than half the total length, sutures impressed. Surface not polished, sculpture of very faint growth lines only. Aperture subtrigonal, peristome complete, the outer margin thin, flattened, and in the line of the spire, the anterior margin also thin and flattened. Length 1·6 mm.

Locality.—Darwin (J. Laseron), holotype and 2 paratypes.

Remarks.—There is no known species with which this, the type of the genus, can readily be compared. In relation to all the species of *Epigrus*, with which alone comparison can be made, it is much smaller, has fewer whorls, and a different shape and texture.

Genus EPIGRUS Hedley

Epigrus Hedley, 1903, p. 355.

Type species *Rissoina cylindracea* Tenison-Woods.

Hedley in designating a type species used *Rissoa ischna* Tate, nom. mut. for *Rissoina cylindracea* Tenison-Woods, not *Rissoa cylindracea* Krynicki. Later, realizing that Tate was wrong as Tenison-Woods's species was described under a different generic name, he restored *cylindracea*, a procedure followed by May and other authors.

Epigrus is a natural and well-defined genus, with an aperture rather similar to that of *Scrobs* but angled posteriorly, a tall, slender spire of many whorls, a thin texture, white, and translucent, the surface smooth and polished. Among the species previously included, *Rissoa badius* Petterd alone has the brown coloration and opaque texture of *Scrobs*, and the separation of this by Iredale (1955, p. 81) as *Badepigrus* removes a discordant element.

EPIGRUS DISSIMILIS (Watson)

Fig. 166

Eulima dissimilis Watson, 1886, p. 522, pl. 37, fig. 5.

The type locality is Port Jackson, N.S.W., and this is a typical Peronian species. Several specimens collected by J. Laseron from Port Curtis now extend its range well into the Solanderian Province. The one figured is 2·8 mm in length. Another specimen was found in shell sand from Noosa Head, farther to the south. Still another specimen from Darwin, though somewhat worn, cannot be distinguished from the same species; and if the last identification is correct, the range is very wide indeed.

EPIGRUS OBESA, sp. nov.

Fig. 167

Shell small, ovate with a convex spire, white, and translucent, the surface smooth and polished. Apex with a large dome-shaped nucleus, the protoconch indistinguishable from the mature shell. Remaining whorls 4, at first increasing rapidly, the penultimate whorl swollen, the body whorl long, margins slightly rounded, sutures distinct but shallow. Aperture ovate, the outer margin contracted within the line of the spire, sharply angled posteriorly, peristome entire, rounded, the outer margin thin, the inner margin wider. Length 2·5 mm.

Localities.—Darwin (J. Laseron), holotype and 5 paratypes; Sweers I. (C. Hedley).

Remarks.—This is a typical *Epigrus* and its occurrence in the Dampierian Province provides an interesting link with the temperate waters of the south. Compared with other known species it can at once be distinguished by its broader and ovate form.

EPIGRUS TRUNCATA, sp. nov.

Fig. 168

Shell small, subcylindrical, white, porcellanous, and opaque. Protoconch indistinguishable from the mature shell, but a small nucleus of less than 1 whorl is coiled upon the apex. Remaining whorls 5, the 1st globose, the next 2 increasing rapidly, slightly rounded with impressed sutures, the penultimate equal in diameter to the body whorl and slightly rounded, the body whorl long, flattened, and cylindrical. Sculpture absent, the surface porcellanous and highly polished. Aperture subtrigonal, short, and wide, laterally extended, the peristome complete, outer margin thin and rounded, anterior margin flattened. Length 3·3 mm.

Locality.—Darwin (J. Laseron), holotype.

Remarks.—The general form and particularly the broad aperture with its flattened anterior margin distinguish this from all other species of the genus, and should make its future recognition easy.

Genus LUCIDESTEA, gen. nov.

Type species *Lucidestea vitrea*, sp. nov.

Minute shells of thin, vitreous texture, quite translucent or transparent, of few whorls with large inflated body whorls, shallowly umbilicate, apertures with complete peristomes, separated from the body whorls, nearly round but slightly angled posteriorly, the margins reflected all round.

The general form resembles *Estea*, but the umbilication and the slight angling of the aperture, and particularly the thin vitreous texture, definitely separate it. From the small, vitreous *Notosetia*, common in Peronian waters, it differs mainly by the complete peristome.

Several species are here described from northern Australia. Their identification is not easy, as the minute size and simple form afford no striking characters for quick recognition. It is only by careful microscopic comparison that the species can be separated. It is probable that many more await discovery.

Lucidestea vitrea, sp. nov.

Fig. 169

Shell minute, broadly conical, vitreous, white, and translucent. Protoconch a small central nucleus followed by a larger short whorl. Remaining whorls 3, rounded, sutures moderately deep, the body whorl large and inflated. Sculpture none, surface smooth and shining. Umbilicus a narrow depression. Aperture ovate, extended anteriorly, angled posteriorly, the peristome entire but close to the body whorl on the inner margin, outer and inner margins rounded and outwardly slightly reflected. Length 1·6 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype and 4 paratypes.

Remarks.—This species, the type of the genus, is like an *Estea* in shape, but differs from all species of that genus by its umbilicus, vitreous texture, and the posteriorly angled aperture.

Lucidestea perforata, sp. nov.

Fig. 170

Shell minute, broadly conical, and inflated, vitreous, white, and translucent. Protoconch small, of about 1 whorl, planoid, coiled on the summit. Mature whorls 3, rounded, sutures deep, the body whorl very large and inflated and contracted at the base into a large, rounded, fairly deep umbilicus. Sculpture none, the surface smooth and shining. Aperture ovate, extended anteriorly, angled posteriorly, peristome complete, quite detached from the body whorl, outer and inner margins rounded, only slightly reflected. Length 1·5 mm.

Localities.—Darwin (J. Laseron), holotype and 3 paratypes; Bowen (J. Laseron), several specimens.

Remarks.—Compared with *L. vitrea* this is a much broader and more umbilicate species, and the aperture is more detached. It evidently has a wide range, as careful comparison shows no difference between the Darwin and the Bowen specimens. It is also tentatively identified from Torres Strait and localities on the Queensland coast.

Lucidestea obesa, sp. nov.

Fig. 171

Shell minute, globose, thin, colourless, vitreous, and translucent. Protoconch a small nucleus just visible centrally above the rim of the apex. Mature whorls 4, the 1st 3 small, the body whorl large and swollen, rounded, sutures well impressed. Sculpture absent, surface smooth and shining. Aperture broadly ovate, obtusely angled posteriorly, peristome complete, the inner margin attached to the body whorl, outer and anterior margins rounded and slightly reflected. Umbilicus funnel-shaped, moderately deep. Length 1·3 mm.

Localities.—Michaelmas Cay (T. Iredale), holotype and 6 paratypes; 5–10 fm, Hope Is. (C. Hedley), common.

Remarks.—In form this resembles *L. perforata*, but it is smaller, has 1 whorl more, the umbilicus is not so wide, and the inner margin of the peristome is not detached from the body whorl.

LUCIDESTEA MACULOSA, sp. nov.

Fig. 172

Shell minute, broadly conical, vitreous, thin, translucent, pale yellow with rows of large white spots below the sutures and the periphery, the base white, Protoconch a minute nucleus immersed in the summit. Remaining whorls 4, rounded, sutures deep, body whorl large, swollen, and somewhat elongated. Sculpture absent, the surface smooth and shining. Aperture ovate, slightly extended anteriorly, angled posteriorly, peristome entire but attached to the body whorl on the inner margin, outer and anterior margins thin, inner margin curved and not reflected. Umbilicus shallow, in the form of a slit. Length 1·2 mm.

Locality.—Lindeman I. (T. Iredale), living on algae, holotype and numerous paratypes.

Remarks.—This differs from the preceding species by its narrower form and in details of the aperture. The colour pattern affords a ready method of recognition.

LUCIDESTEA LATEREA, sp. nov.

Fig. 173

Shell minute, broadly conical, thin, translucent, pale dull yellow with a brown patch on the base. Protoconch as in other species, a small nucleus only visible on the summit. Remaining whorls 4, rounded, sutures impressed, the penultimate whorl relatively long, the body whorl large and tumid. Sculpture absent, surface smooth and shining. Aperture ovate, slightly extended anteriorly and angled posteriorly. Peristome entire, the inner margin adhering to the body whorl, outer and anterior margins thin and rounded, not reflected, the anterior margin making a slight angle with the inner margin, which is very slightly reflected. Umbilicus shallow, in the form of a narrow slit. Length 1·6 mm.

Locality.—Bowen (J. Laseron), alive on algae, holotype and 6 paratypes.

Remarks.—This is very close in form to *L. maculosa*, but is larger, has a different colour pattern, and varies in contour, and the aperture is also slightly different.

LUCIDESTEA CAPRICORNEA (Hedley)

Fig. 174 (after Hedley)

Amphithalmus capricornea Hedley, 1907, p. 495, pl. 17, fig. 22.

The type came from 17 to 20 fm, Mast Head I., Capricorn Group, where it is stated to be abundant. The length is given as 1·5 mm. Apart from Hedley's excellent figure and description, the colour should make this species easy to recognize. It is given as cream, the upper whorls pale orange, the lower with bands of pale orange on the periphery and shoulder, the umbilicus and columella stained a much deeper orange.

Hedley placed this species in *Amphithalmus*, used at the time for Australian species of *Scrobs*, but apart from the detached aperture it is obviously a misfit, the umbilicus alone separating it. On the other hand it fits well with *Lucidestea*, only differing in detail from the Darwin species *L. perforata*.

LUCIDESTEA SUBLACŪNA, sp. nov.

Fig. 175

Shell minute, broad, silhouette almost triangular, thin, and translucent, colourless to pale yellow or buff. Protoconch minute, just visible on the rounded summit. Remaining whorls 4, rounded, slightly restricted at the sutures, body whorl large and swollen at the base. Sculpture absent except for faint, microscopic growth lines. Aperture subrhomboidal, extended anteriorly, outer margin thin, nearly straight, inner margin also almost straight, reflected. Peristome complete, angled posteriorly. Umbilicus a narrow slit. Length 2 mm.

Locality.— 17–20 fm, Mast Head I., Capricorn Group (C. Hedley), holotype and 7 paratypes selected from tube of specimens.

Remarks.—This is closest to *L. laterea*, but is larger and has a different shape, narrower at the summit and broader at the base.

Genus MESODESTEA, gen. nov.

Type species *Mesodestea resima*, sp. nov.

Thin, translucent, conical, with few whorls, resembling *Lucidestea* in the rounded whorls restricted at the sutures, the complete peristome reflected over the inner margin, but larger and without an umbilicus.

MESODESTEA RESIMA, sp. nov.

Fig. 176

Shell small, broadly conical, apex blunt, white, thin, and translucent. Protoconch small, planoid, coiled on the summit. Mature whorls 4, increasing regularly, rounded, restricted at the sutures, body whorl large, more than half the total length. Sculpture none, the surface vitreous and shining. Aperture broadly ovate, the peristome complete, quite detached from the body whorl, the outer margin thin, inner margin flattened, reflected, the reflection widening into a tongue posteriorly. Length 3·2 mm.

Locality.—Darwin (J. Laseron), holotype.

Remarks.—This is another of the small Australian shells, whose characters, either specific or generic, will not fit with any other. The nearest comparable group is *Lucidestea*, but it differs from all the species of this genus by being larger and without an umbilicus. The other most distinguishing character is the wide reflection of the inner margin posteriorly over the body whorl.

Genus VITRICITHNA, gen. nov.

Type species *Cithna marmorata* Hedley.

Shell minute, thin, translucent, few whorls, white or coloured, sometimes with alternate translucent and opaque stripes. Whorls rounded, smooth, body whorl large and swollen. Aperture with incomplete peristome, anterior margin more or less flattened, making an angle with the nearly straight inner margin, which is reflected over the columella.

The nearest genus with a superficial resemblance is the Atlantic deep-water *Cithna* A. Adams (1863, p. 113), which has been the repository of many species from various localities, apparently for the main reason that they will not fit elsewhere. For instance, Hedley described a deep-water shell from off Narrabeen, N.S.W., as *Cithna angulata*, and this is certainly not congeneric with his *marmorata* from Queensland, and this also needs a new generic name. *Vitricithna* is perhaps nearer to *Notosetia* Iredale, differing chiefly in the sharply angular aperture.

Vitricithna marmorata (Hedley)

Figs. 177 (after Hedley) and 178

Cithna marmorata Hedley, 1907, p. 498, pl. 18, figs. 27–28.

The type locality is 17–20 fm, Mast Head I., Capricorn Group, the length of the type 1·95 mm, and Hedley also records it from 5 to 10 fm, Hope Is. Most of the material in the Australian Museum has unfortunately disintegrated in the tubes, but Hedley's excellent description and figure should make its future identification certain. The colour is given as buff or white, with or without irregular streaks or dots.

Two specimens from Michaelmas Cay, though conforming in form and size to the type, have a curious pattern, axially arranged, of alternate opaque and translucent stripes. These are tentatively left under *marmorata*, and one of them, 1–9 mm in length, is here figured for comparison (Fig. 178).

Vitricithna relativa, sp. nov.

Fig. 179

Shell minute, conical, relatively solid, with a few irregular, opaque white patches on a colourless, translucent ground. Protoconch minute, of less than a whorl, on the summit. Remaining whorls 5, increasing regularly, slightly rounded, sutures not deep. Surface smooth and vitreous. Aperture subrhomboidal, peristome incomplete, outer and anterior margins slightly rounded, the anterior margin sharply angled with the inner margin, which is widely reflected over the columella. Length 1·7 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype and 18 paratypes.

Remarks.—This species differs from *V. marmorata* by being smaller and rather more solid, having a different contour, and with 1 whorl more.

Genus MELLITESTEA, gen. nov.

Type species, *Mellitestea simplex*, sp. nov.

Shell thin, translucent, and smooth, with a conical, elongated spire, slightly rounded whorls, and impressed sutures. A very faint spiral keel on the periphery.

Peristome complete, inner margin reflected, aperture subangular posteriorly. Not umbilicate.

A new genus is necessary for the type species, as it will not fit in any other in the family. The longer spire and absence of an umbilicus separate it from *Lucidestea*, and the complete peristome from *Vitricithna*. *Mesodestea* is much larger, and has a long body whorl and quite a different facies.

MELLITESTEA SIMPLEX, sp. nov.

Fig. 180

Shell minute, elongately conical, thin, translucent, yellow-brown. Apex subacuminate, with a minute infolded nucleus. Remaining whorls 6, slightly rounded, sutures impressed, a faint spiral keel on the periphery, but this is only visible in certain lights. The surface is shining and otherwise free from sculpture. Aperture ovate, just free from the body whorl, from which it is separated by a nearly straight channel, outer margin thin, anterior margin subangular with the inner margin, which is reflected over the columella. Length 1·5 mm.

Locality.— 5–10 fm, Murray I., holotype and 6 paratypes.

Remarks.—The paratypes vary slightly, one being larger, about 2 mm in length. Some specimens also show the slight peripheral keel more than others.

Genus CYCLONIDEA, gen. nov.

Type species *Cyclonidea carina*, sp. nov.

A genus of uncertain classification, the spire elongate, turreted, restricted greatly at the sutures, thin, white, and translucent, the sculpture of a few distant, sharp, prominent spiral keels. Aperture polygonal, no varix, the anterior margin angled, inner margin reflected, peristome incomplete, base excavate, without an umbilicus.

This curious little shell may not belong to the Rissoidae at all. In some of its characters it resembles *Turritella*, in others some of the Peronian genera which had previously been referred to the fossil *Mathilda*. Its inclusion with the Rissoidae is here purely tentative.

CYCLONIDEA CARINA, sp. nov.

Fig. 181

Shell small, elongate, turreted, white, thin, and translucent. Protoconch large, of $1\frac{1}{2}$ smooth whorls, the nucleus large, the next whorl inflated. Mature whorls 5, turreted, with sloping shoulders, greatly restricted at the sutures, body whorl short. Sculpture of 2 prominent, narrow, distant keels on each whorl, with an extra keel on the base of the body whorl, the uppermost keel standing out and giving a marked angularity to the whorls. Faint axial striae are just visible between the keels. Base excavate. Aperture polygonal, produced anteriorly, indented by the keels, sharply angular anteriorly, outer margin thin, inner margin widely reflected over the columella. Length 2·8 mm.

Locality.—Christmas I., holotype.

Remarks.—Like other small, unique shells from Christmas I., the characters are so distinctive that they cannot be readily compared with any other known species.

Genus DIALA A. Adams

Diala A. Adams, 1861, p. 242.

Type species *Diala varia* A. Adams, loc. cit., p. 243.

A liberal translation of the brief Latin description reads: "Imperforate, ovate conical, semi-opaque, variably coloured, whorls simple, aperture ovate, whole in front, margin simple". Adams designated no type, but described four species, all from China, of which the first, *D. varia*, was designated the type species by Smith (*Proc. Zool. Soc. Lond.* **1875**: 538). The original description of *D. varia* was quite inadequate and was unaccompanied by any figure, and recognition would be impossible had not Hedley (1913, p. 286, Plate 18, Fig. 56) published an excellent figure of a specimen from China in the British Museum, which is probably a paratype, though not designated as such.

This shows a small, broadly conical shell with flat sides, the sutures not impressed, the apex blunt, the texture thin, with no sculpture, but a variegated colour pattern, the aperture ovate, the peristome incomplete, the margins thin and rounded, the inner margin reflected over the columella.

Many Australian species come broadly within this description, and the genus has been used with little modification by various authors in the southern Australian provinces. The northern Australian species are for the most part undescribed and there is considerable diversity among them, so much so that it is possible that the relationship between some of them is more apparent than real. It has, however, at this stage been found impossible to select any one character or group of characters by which they can reasonably be divided, and they are left for the most part under *Diala*. An exception is made with one group which closely resembles the Atlantic *Alaba*. These have been described separately as a new genus *Australaba*. In addition to this Iredale (1955, p. 81), proposed *Dialessa* for the very thin, transparent, sculptureless Peronian species *Diala translucida* Hedley.

Amongst the northern species the protoconch will be found very useful for specific determination, and a broad division may be made between species with minute protoconchs and acicular apices and those with large protoconchs and blunt apices. Some species have flattened whorls with the sutures barely visible, others have the whorls slightly rounded and the sutures narrowly channelled. Sculpture when present is spiral, narrow threads or striae, which may be persistent over the whole shell or restricted to the base. Irregular varices or swellings are sometimes present, but may be present or absent in the one species. The northern species are generally very constant, but one or two show remarkable variation, particularly in size or width. Colour when present is a useful guide, and this character does not show the same variation within a species that it does in southern waters. The operculum of *D. virgata* has been described by Hedley (1899, p. 423) as thin, corneous, ovate, and paucispiral.

DIALA ALBUGO (Watson)

Fig. 182

Alaba (*Diala*) *albugo* Watson, 1886, p. 568, pl. 42, fig. 3.

The type locality is 8 fm, off Wednesday I.; the length given is 0·13 in., or a little over 3 mm. Watson's figure is an excellent one, but his description of the colour pattern suggests that it is slightly composite, and may include specimens of another closely related species, which is hereafter named *D. conspicua*. The species evidently has a wide range on the Barrier Reef, and a live series collected by J. Laseron from the Capricorn Group far to the south absolutely match Watson's figure. The one figured is 2·5 mm in length. The colour is cream with very regular broken, spiral bands of brown filling the shallow spiral grooves. A series from Michaelmas Cay is slightly larger and more variable in colour, but all have the broken spiral bands, though more numerous in some specimens, and occasionally reduced almost to dots.

DIALA CONSPICUA, sp. nov.

Fig. 183

Shell small, broadly and regularly conical, fairly solid, porcellanous, white in colour with 4 narrow spiral bands of chestnut on each whorl, the 2 upper bands within a zone of paler shade, the base chestnut with rows of white spots, the colour bands visible within the aperture. Apex acute, a small nucleus followed by a conical whorl, but the protoconch indistinguishable from the mature shell. Whorls 6, flattened, the sutures hardly distinguishable, the body whorl subangled at the periphery. Aperture ovate, rather narrow and extended anteriorly, outer margin thin, inner margin broadly reflected over the columella. Sculpture of narrow, shallow, spiral grooves, largely obscured by the coloured bands but more apparent on the base. Length 2·7 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype and several worn specimens.

Remarks.—This is very close to *D. albugo*, but has a different colour pattern, the whorls are flatter, the body whorl is not swollen, and the aperture is narrower and more produced anteriorly.

DIALA FOSSA, sp. nov.

Fig. 184

Shell small, relatively solid, broadly conical with a slightly convex spire, white, the columella edged with brown. Protoconch smooth, small, of less than a whorl, flatly coiled upon the summit. Remaining whorls 5, nearly flat, the sutures narrowly but sharply channelled, body whorl large, about one-half the total length. Sculpture spiral and well defined, of rather broad, flattened ribs separated by narrow channels, about 7 on the penultimate and 18 on the body whorl. In some specimens the spirals are more numerous and narrower. Aperture broadly ovate, narrowly channelled posteriorly, only slightly extended anteriorly, outer margin thin and rounded, inner margin very slightly reflected. Length 3 mm.

Localities.—Michaelmas Cay (T. Iredale), holotype and 7 paratypes; Bowen (J. Laseron), several specimens.

Remarks.—This can readily be distinguished from the 2 previous species by the protoconch, the much stronger spiral sculpture, and the channelled sutures. The line of colour on the columella is a good recognition point. It is one of several species that have at different times been identified as *Alaba martensi* Issel, a species from the Red Sea.

DIALA PREMERIS, sp. nov.

Fig. 185

Shell small, thin, conical, colour pale buff. Protoconch small, of 1½ smooth whorls. Mature whorls 5, rounded, restricted at the sutures. Sculpture well defined, of narrow, raised, spiral cords, separated by about twice their width, 7 on the penultimate and about 14 on the body whorl. Aperture broad and ovate, slightly extended anteriorly, the outer margin regularly rounded, subangled anteriorly, the inner margin nearly straight and only slightly reflected. Length 3·1 mm.

Localities.—Thursday I. (J. Laseron), holotype and 3 paratypes; 20 fm, off Endeavour Reef (C44831 in Australian Museum), common.

Remarks.—This is close to *D. fossa*, but can readily be distinguished by the much more rounded whorls. The protoconch is also different.

DIALA WATSONI, nom. nov.

Fig. 186

(?) *Barleeia imbricata* Watson, 1886, p. 584, pl. 43, fig. 2, not *Diala imbricata* A. Adams, 1862, p. 397.

When Watson described his species he expressed doubt of its genus, and its inclusion in *Barleeia* was provisional. It actually bears little resemblance to this European genus, and in all its characters is a true *Diala*. The specific name thereupon becomes preoccupied and must be changed.

The type locality is Torres Strait, but the specimen here figured is from Darwin, much farther to the west. Its length is 2·6 mm. The Darwin specimens match Watson's figure and description very closely. It may be added that they are a creamy white, the texture is porcellanous and shining, and there is a touch of brown on the columella similar to that in *D. fossa*. The sculpture, however, though spiral, is very faint, and the upper whorls are quite smooth.

DIALA PLANALBA, sp. nov.

Fig. 187

Shell very small, regularly conical, thin, white, and translucent. Protoconch a large nucleus within the summit. Remaining whorls 5, nearly flat, separated by narrow but deeply channelled sutures, the body whorl subangled below the periphery. The surface is smooth and shining, the only sculpture several narrow spiral striations just below the periphery. The base is smooth. Aperture subrhomboidal, slightly extended anteriorly, outer and anterior margins flattened, inner margin nearly straight and only slightly reflected. Length 2·2 mm.

Localities.—Bowen (J. Laseron), holotype; 20 fm, off Endeavour Reef (A. R. McCulloch).

Remarks.—The restriction of the spiral sculpture to a narrow zone just below the periphery at once distinguishes this from all the other species discussed.

DIALA CACUMENATA, sp. nov.

Fig. 188

Shell of medium size, regularly conical, acuminate, thin, translucent, pale yellow-buff with faint, narrow, irregular, darker streaks running in an axial direction. Apex acicular, the protoconch very small, of 1½ whorls with a minute apex. Remaining whorls 7, short, flat, separated by very narrow, shallow, channelled sutures, the body whorl large and subangular at the base. Sculpture spiral, restricted to the base of the body whorl, of about 7 faint spiral lirae, the remainder of the shell smooth. Aperture ovate, produced anteriorly, the outer margin thin and flattened, anterior margin rounded, inner margin nearly straight and very slightly reflected. Length 4·3 mm.

Locality.— 5–10 fm, Hope Is. (C. Hedley, C27344 in Australian Museum), holotype and 10 paratypes selected from full tube of specimens.

Remarks.—The faint sculpture, restricted to the base, distinguishes this from most of the species here discussed. The colour pattern is constant on all the specimens examined. *D. cacumenata* is one of several species which at different times have been identified as *D. semistriata* Phillipi.

DIALA VESTIGIA, sp. nov.

Fig. 189

Shell of medium size, elongated, conical, spire slightly convex, thin, opaque, surface shining, colour cream. Apex acicular, protoconch of 2 minute whorls. Remaining whorls 7, slightly rounded and restricted at the sutures, the body whorl rounded at the base and not subangular. Spiral sculpture restricted to the base of the body whorl, consisting of fine, close lirae. In addition, oblique axial riblets also occur on the upper part of the body whorl, where they are regular, but they become fainter and more irregular as the spire is ascended. Aperture ovate, elongate, extended anteriorly, outer and anterior margins thin and regularly rounded, inner margin rounded and only slightly reflected. Length 4·7 mm.

Locality.— 5–10 fm, Hope Is. (C. Hedley), holotype.

Remarks.—The holotype was readily separated from the tube of *D. cacumenata*, in which it had been included, by its narrower form, more rounded whorls, rounded and not subangular base, and more elongate and narrower aperture.

DIALA DIFFILATA, sp. nov.

Figs. 190 and 191

Shell relatively large, conical, very variable in width, apex aciculate, texture thin, translucent, colour pale buff, with occasional patches of brown on the earlier whorls. Apex aciculate, the protoconch of 2 minute whorls. Mature whorls 8, increasing regularly, slightly rounded, restricted at the sutures, the body whorl large and swollen. Sculpture of fine spiral threads, the furrows indented with microscopic axial threads. The spirals number about 9 on the penultimate and about 25 on the body whorl. There is no other sculpture on the holotype, but many specimens of both the broad and narrow forms show irregular rounded, axial ribs or swellings, varying both in size and distribution, but more developed on the last 2 whorls and absent on the base. A narrow specimen showing these ribs is here figured (Fig. 191). Aperture broadly ovate, outer and anterior margins thin and evenly rounded, inner margin slightly reflected. Length, Figure 190 (holotype) 6·4 mm, Figure 191 5·3 mm.

Localities.—Bowen (J. Laseron), alive on seaweed, holotype and 20 paratypes; Lindeman I., common in similar habitat.

Remarks.—This species is remarkably variable in form, the width varying from that of the holotype to even narrower specimens than that of Figure 191. The presence or absence of axial swellings also adds to the variability. Nevertheless recognition is easy; there is a uniform facies, the large, very thin shell, the buff coloration, and the sculpture all being distinctive. The series from Lindeman I. show exactly the same characters and variation as that from the type locality.

DIALA CENTO, sp. nov.

Fig. 192

Shell large for the genus, regularly conical, texture opaque and porcellanous, polished, colour cream with rhomboidal patches of chestnut in the centre of the whorls, and narrow bars above and below, arranged spirally and visible within the aperture, apex very dark, almost black. Protoconch large, making the apex obtuse, of 1½ whorls, the nucleus small, the next whorl swollen. Mature whorls 6, flat, the sutures shallow but distinct, body whorl subangled at the base. Spiral sculpture confined to base of body whorl, where about 6 narrow striae are partially obscured by the coinciding colour pattern. Aperture broadly ovate, the outer and anterior margins thin and rounded, inner margin long, nearly straight, and very slightly reflected. Length 7 mm.

Locality.—Keppel Bay (J. Laseron), living on seaweed, holotype and 20 paratypes.

Remarks.—This is the largest *Diala* here discussed, and the blunt apex also distinguishes it from most of the other species. The colour pattern is fairly constant, though there is variation in the size of the chestnut, rhomboidal patches, and in some specimens they are reduced to narrow bars.

DIALA TUMEROSA, sp. nov.

Fig. 193

Shell minute, conical, slightly convex, white, texture thin, porcellanous, and opaque. Protoconch small, of 1½ whorls. Remaining whorls 6, short, rounded, restricted at the sutures. Sculpture absent, the surface smooth and polished, but on the last 2 whorls, particularly the body whorl, a few low, rounded ribs or swellings have developed, noticeable at the top but fading at the periphery. Aperture small, subrhomboidal, the outer margin thin and flattened, the anterior margin flattened, but possibly not quite as flat as shown in the holotype, which may be slightly broken, inner margin straight, reflected, the reflection narrowing anteriorly. Length 2 mm.

Locality.—20 fm, off Endeavour Reef (A. R. McCulloch, C44834 in Australian Museum), holotype and 12 paratypes selected from full tube.

Remarks.—Though obviously very common, it was difficult to find specimens in good enough condition to describe, as most had deteriorated in the tube. It is the smallest of all the species here discussed, and it differs also in form, the porcellanous texture, and the absence of spiral sculpture.

Genus PARADIALA, gen. nov.

Type species *Paradiala supraflecta*, sp. nov.

A genus similar in most characters to *Diala*, thin and with spiral sculpture, but differing in the widely reflected inner margin of the aperture and the complete peristome. The latter character alone is considered of sufficient importance to warrant generic separation, as it implies a quite different relationship.

PARADIALA SUPRAFLECTA, sp. nov.

Fig. 194

Shell of medium size, conical, very thin, white, and very translucent. Protoconch large, of 1½ whorls, the nucleus large, the next whorl short. Mature whorls 5, short, slightly rounded, restricted at the sutures, the penultimate whorl slightly swollen. Sculpture of fine, rounded, spiral cords, about their own width apart, about 8 on the penultimate and 13 on the body whorl, the earlier whorls nearly smooth except for a few faint axial puckers. Aperture broadly ovate, the peristome entire, the outer margin thin, the inner margin widely reflected over the columella, then adhering to the body whorl. Length 4·2 mm.

Locality.— 17–20 fm, Mast Head I., Capricorn Group (C. Hedley, C19625 in Australian Museum), holotype and 7 paratypes selected from full tube.

Remarks.—The complete peristome at once separates this from all species of *Diala*, with which alone it can be compared. The Australian Museum specimens have been labelled *Diala martensi* Issel, a Red Sea species which bears only superficial resemblance.

Genus AUSTRALABA, gen. nov.

Type species *Australaba bowenensis*, sp. nov.

A genus like *Diala* in most characters, but with much rounded whorls and deeper sutures, and with the apertures sharply angled anteriorly. The sculpture is of spiral cords throughout, and there are also numerous but irregular rounded axial ribs or swellings, beginning at the sutures and fading on the base, which are opaque and appear white, affording a strong contrast to the translucent texture of the remainder of the shell. This gives the group a very distinctive facies. The South Australian species *Alaba pagadula* A. Adams and *Diala imbricata* A. Adams probably come here, also the Western Australian *Alaba vibex* A. Adams.

AUSTRALABA BOWENENSIS, sp. nov.

Fig. 195

Shell relatively large, elongate, conical, variable in width, translucent, but the axial ribs opaque, white with a few small brown patches, irregularly dispersed. Apex acuminate, the protoconch a small nucleus, followed by about 1 more whorl, but indistinguishable from the mature shell. Remaining whorls 8, well rounded, restricted at the sutures. Sculpture a number of irregular rounded, axial ribs, opaque, varying much in size, more numerous on the median whorls, 1 or 2 very large ones on the body whorl, ceasing at the periphery. Spiral sculpture of closely packed threads, their channels with microscopic axial striations, sometimes but not always overriding the axial ribs. Aperture ovate, the outer and anterior margins thin, the anterior margin sharply angled with the inner margin, which is nearly straight and reflected. Length of holotype 7·3 mm.

Locality.—Bowen (J. Laseron), holotype and 6 paratypes.

Remarks.—The form is variable, some specimens being much broader than the holotype. The small protoconch and the acuminate apex at once distinguish this from the other northern species *A. difformis* here described.

AUSTRALABA DIFFORMIS, sp. nov.

Figs. 196–198

Shell of medium size, exceedingly variable in form, the holotype elongate, other specimens much broader, translucent, the axials white and opaque. The protoconch is much larger than in *A. bowenensis*, making the apex obtuse. Description otherwise nearly as in *bowenensis*, except that the average size is smaller, there are fewer whorls, the early whorls are nearly quite smooth, and the axial ribs are generally fewer, though the last character is very variable and unreliable. The aperture is also similar, though the margin varies according to whether it coincides with one of the axial ribs or not. Length of holotype 3·9 mm (Fig. 197); of paratype (Fig. 196) 3·5 mm; of specimen of Figure 198 4·5 mm.

Localities.—Darwin (J. Laseron), holotype and 13 paratypes; Sweers I. (C. Hedley, C15553 in Australian Museum), common (Fig. 198).

Remarks.—The series from Sweers I. are doubtfully referred to this species as there are small differences, mainly in the aperture; but in view of the extreme variability it is not certain that these are specific or even racial. They are generally larger, the specimen of Figure 198 measuring 6·5 mm in length. This series has been labelled *Alaba vibex*? A. Adams, the Western Australian species. Adams's original description without figure of *vibex* is quite insufficient for identification, but Hedley (1913, p. 288, Plate 18, Fig. 62) published a figure of one of two specimens in the British Museum, from Shark Bay, W.A., thought to be types but not designated as such. This shows a different species, the main difference being in the aperture.

Genus OBTORTIO Hedley

Obtortio Hedley, 1899, p. 412.

Type species *Rissoa pyrrhacme* Melvill & Standen (1897, p. 310, Plate 11, Fig. 310).

Shells of irregular growth, thin, elongate, more or less cylindrical, the last 3 or 4 whorls often nearly equal, the early whorls increasing rapidly to form a conical apex. Sculpture generally discrepant, both spiral and axial, the axial sculpture often present only on the median whorls and fading on the body whorl. Aperture ovate, peristome incomplete, outer margin thin and without a varix.

The type species from Lifu has a small sculptured protoconch which Hedley considered the chief character of generic value, but none of the other species he included in *Obtortio* had this protoconch, nor does it occur in any of the Australian species here discussed. Nevertheless the genus is a good one, with a general facies making it easy to recognize.

If recognition of the genus is easy, determination of the species is just the opposite. In addition to the type Hedley included *Alaba striata* Watson and *Alaba fulva* Watson in *Obtortio*, and synonymized *Rissoa joviana* Melvill & Standen under *fulva*, remarking that he was "not satisfied that all 4 names do not apply to aspects of one polymorphic species". The distinctive sculptured protoconch of the type species separates this at least from the others mentioned; nevertheless the variability of many other species is so great that it has been exceedingly difficult to find dependable characters to determine specific limits. If the variation depended on location, the solution no doubt would be that geographical races had evolved, but unfortunately the individual variation is often greatest in one locality, notably at Bowen, so this simple answer to the problem cannot be adopted. Careful study of the protoconch does, however, as so often in the Gasteropoda, remove some of the difficulty. It has been found that all the Australian forms fall into two series: those with fine, often mucronate protoconchs, and those with large protoconchs, giving the shells blunt apices. Other small differences in the protoconchs serve as a further guide to species, and in other cases there is distinctive sculpture which can be depended upon. This will be further discussed when describing the species themselves.

The systematic position of *Obtortio* is not yet certain. The animal is unknown, nor has the operculum of any species yet been recorded. Hedley initially included it in the Pyramidellidae, but later (1909, p. 439) transferred it to the Rissoidae. The general form, texture, and aperture resemble *Diala*, and it is possible that they are closely related and might together constitute a new family.

OBTORTIO FULVA (Watson)

Figs. 199–203

Alaba (*Stiliferina*?) *fulva* Watson, 1886, p. 571, pl. 42, fig. 7.

If all the identifications here made are correct this is the most variable of all the species examined. Watson's type came from 8 fm, off Wednesday I., the length given being 0·013 in., that is, a fraction over 3 mm, and the colour dark yellow. A specimen from a close locality, 4–14 fm, Albany Passage (Fig. 199) is a faded yellow and its length 4·2 mm. From Bowen on the coast further south a large series collected by J. Laseron shows remarkable variation, so much so that at first sight it appeared that there were several species. Of these 3 are now figured: Figure 200, yellow grading to brown at the summit and 4·7 mm in length; Figure 202, uniformly deep brown and almost black, 3·8 mm in length; Figure 201, narrower and more cylindrical, white with a brown apex and 4·5 mm in length. Most of the Bowen specimens fall into distinct colour groups, but variations in form and sculpture cut right across the colour. The chief colour patterns are:

(*a*) Uniformly deep red-brown,

(*b*) Yellowish with a deep brown band below the suture, (*c*) Lower half yellowish, merging into deep brown at the summit,

(*d*) White with a brown apex.

The protoconch is uniform as in Figure 202, very small and conical, following the line of the spire, of 2½ smooth whorls, the nucleus relatively large and slightly tilted. The mature sculpture is always discrepant, beginning on the earlier whorls as sharp spiral keels, generally 2 in number. This may persist alone up to the 4th whorl, while axial sculpture may appear as early as the 2nd or as late as the 4th, varying from ill-defined rounded ribs to ribs which are narrower and sharper, and varying in number in different specimens from 16 to 20 to the whorl. The median whorls are generally more or less clathrate. The axial ribs become weaker on the last whorls and always fade on the base of the body whorl, where the spiral sculpture persists as well-defined narrow ribs right to the base. The number of mature whorls is 7 or 8. The aperture is reasonably constant throughout, the inner margin only slightly reflected over the columella. Specimens from other localities vary within these limits, and attempts to divide them into different species or races have so far failed.

OBTORTIO FULVA AXIALIS, subsp. nov.

Figs. 204 and 205

A series collected by J. Laseron from Darwin have the general characters of *O. fulva*, but differ slightly and constantly enough to suggest that here at least is sufficient departure from the specific stock to warrant racial separation. The protoconch is close to that of *fulva*, small, but a 3rd short smooth whorl is considerably wider, giving the apex a different appearance. Sculpture also does not begin as spiral keels, but as faint axial ribs, and these, though irregular, are more prominent than the spirals on the later whorls to where they fade on the base of the body whorl. The axials are also fewer, ranging from 12 on the early whorls to 16 on the body whorl. Spirals number about 7 on the earlier whorls and about 13 on the body whorl. Mature whorls number only 6, and the length of the holotype is 4·6 mm.

OBTORTIO STRIATA (Watson)

Figs. 206–210

Alaba striata Watson, 1886, p. 569, pl. 42, fig. 6.

The identification of this species is doubtful, nor is it certain that all the specimens referred to it are racially or even specifically the same. The type locality is Levuka, Fiji, and the figure of the type suggests that it may not be quite mature. If all the identifications are here correct, the species, like *O. fulva*, is extremely variable in form, sculpture, and size. Only the protoconch and the aperture are constant, and these approximate closely to *fulva*, as do the axials, which are never strong. Examination of much Queensland material, however, shows that 2 general forms can be distinguished throughout, *O. fulva* with a nearly conical shell in which the protoconch continues the line of the spire, and *O. striata* with a cylindrical to ovate spire, the protoconch appearing as a small peg on the summit of a comparatively large initial mature whorl. The colour of *striata* is nearly always white with a brown tip.

A long series collected by A. R. McCulloch from the Barrier Reef off Cairns (C46134 in the Australian Museum) are constant in sculpture and all have the typical coloration. They vary somewhat in shape, one (Fig. 206) being almost ovate in shape. It is 4·2 mm long. Other specimens are more cylindrical, including one very large shell over 5 mm in length. All are broader than any specimen of *O. fulva*. That of Figure 207 is from Murray I. It is pure white and a little worn, 3·9 mm in length, the form is markedly cylindrical, and the sculpture is much finer than the Cairns specimens. The specimen of Figure 209 is from Bowen and is still smaller, only 2·9 mm in length. It also is white, markedly cylindrical, and has fewer and less distinct axials.

It is unfortunate that the problem of the limitations of these two species is not yet definitely solved. Only further examination of much additional material, particularly live material, can determine whether additional species or races are involved. It is felt that the proposal of new names at this stage might well confuse the issue for future workers, but that the publication of several figures and of the limited information available will provide a basis for further work.

OBTORTIO COLUMNA, sp. nov.

Figs. 211–214

Shell small, cylindrical, broad, tapering at the summit, thin, white, and translucent. Protoconch small but larger than in either of the preceding species, of 1½ whorls, a fairly large nucleus, followed by a smooth, inflated whorl. Incipient sculpture appears on the next whorl, which is much larger. Remaining whorls 4, the penultimate as large as the body whorl, all inflated and restricted at the sutures. Sculpture weak, the axials irregular, hardly visible on the early whorls, fading on the base. There are about 20–22 axials on the body whorl, but the number is variable. The spirals are regular low, rounded ribs, more prominent on the base. Aperture relatively small, outer margin thin and rounded, inner margin curved and hardly reflected. Length 3 mm.

Localities.—Darwin (J. Laseron), holotype (Fig. 211) and 7 paratypes; Bowen (J. Laseron), 2 specimens (Fig. 213).

Remarks.—The protoconch at once distinguishes this from both *O. fulva* and *O. striata*. It is larger and at the same time has 1 fewer whorl. The sculpture and form resemble *O. striata* more than *O. fulva*. The Bowen specimens are very close to those from Darwin, showing the species to have a wide range. That figured for comparison is 2·5 mm in length.

OBTORTIO VULNERATA Hedley

Figs. 215 and 216

Obtortio vulnerata Hedley, 1909, p. 439, pl. 40, fig. 52.

The type came from the Hope Is., its length being 4 mm. A series from Michaelmas Cay, one of which is figured, do not quite match the type, the colour being uniformly white instead of white with a brown apex and columella, but in view of the variability of most of the species, the variation is well within the usual specific limitations. The length of the specimen figured is 3·7 mm.

Compared with *O. fulva* the protoconch is larger and nearer to that of *O. columna*, while the coarse clathrate sculpture separates it from both these species. Though slightly variable in form it is also uniformly more slender than the others, and generally subcylindrical in shape, the last 4 whorls often nearly equal. The enlargement of 1 or 2 of the axial ribs on the body and penultimate whorls into varices is also a good recognition point.

OBTORTIO PERPARVULA PROGREDA, subsp. nov.

Fig. 217

Watson (1886, p. 554, pl. 38, fig. 3) described *Bittium perparvulum* from 18 fm, Tongatabu, between New Caledonia and Fiji, and recorded it also from Torres Strait, observing that the latter specimens are rather larger than the type. A species very abundant at Murray I. is probably that studied by Watson, and the same species is also common at Darwin. The specimen figured is from Darwin, its length 2·8 mm. The colour is white, the apex is white, but the early mature whorls are pale brown, and there is a splash of pale brown on the columella. Compared with typical *perparvula* the proportions and shape are much the same, but the sculpture is much more rugose, and the axial ribs are more prominent, particularly on the median whorls, and are more numerous. The Murray I. specimens are white without the brown band, very close to those from Darwin but on the average slightly less rugose. It would seem that geographical differentiation has here taken place, sufficient to produce a distinct race but not a species.

OBTORTIO RUGOSA, sp. nov.

Figs. 218 and 219

Shell of medium size, elongate, conical, white with a brown apex. Protoconch minute, smooth, of 1½ whorls, nucleus relatively large. Remaining whorls 9, increasing regularly, slightly rounded, sutures restricted and deep. Sculpture on the 1st 3 whorls spiral only, the 1st with 1, the 2nd and 3rd each with 2 sharp spiral keels. On the remainder the sculpture is strongly clathrate, the spirals increasing from 2 to 3, with 4 additional smooth keels on the base of the body whorl. The axials are strong, about 18 to the whorl, rising into gemmules at their intersections with the spirals. Aperture subquadrate, outer margin thin, anterior margin angled with the inner margin, which is nearly straight and slightly reflected. Length 3·7 mm.

Locality.—Christmas I., holotype and 12 paratypes.

Remarks.—This species resembles *O. vulnerata*, but is without varices and has fewer spirals; it also differs from both *vulnerata* and *perparvula* by the protoconch and spiral keeling of the earlier whorls.

OBTORTIO VARICOSA, sp. nov.

Fig. 220

Shell small, conical, of nearly regular growth, comparatively solid, apex blunt, colour a uniform yellow-brown. Protoconch large, of 2 whorls, the nucleus large, sculpture beginning as faint axial ribs. Mature whorls 5, short, rounded, sutures deep, penultimate whorl slightly swollen. Sculpture strongly clathrate but not tuberculate, the axial ribs narrow, well defined, and raised, ceasing below the periphery on the body whorl, the spirals narrow, sharp, and defined, but not so high as the axials. On the body whorl 2 of the axials have been thickened into broad and prominent varices. The axials number 14 to the whorl, the spirals 3–4 on the earlier whorls and 9 on the body whorl, the lowest 3 of which are smooth. Aperture ovate, outer margin thickened on the holotype by the development of one of the varices, inner margin slightly curved and broadly reflected over the columella. Length 3·1 mm.

Locality.—Bowen (J. Laseron), holotype and 3 paratypes.

Remarks.—This is the first of several species with large protoconchs, giving the shells blunt apices and at once distinguishing them from those already described.

OBTORTIO AMBIQUA, sp. nov.

Fig. 221

Shell of medium size, elongated, conical, of regular growth, white, with a touch of brown on the columella. Protoconch large, smooth, of 1½ whorls, the nucleus large, the next whorl inflated, sculpture beginning gradually as faint axial ribs. Mature whorls 6, rounded, sutures deep. Sculpture clathrate, the axials narrow, sharp, distant, and well elevated, fading on the base, 12–14 to the whorl. On the body whorl 2 of the axials rise as sharp varices well above the suture. Spirals narrow, low, and not prominent but rising to points where they cross the axials, closer together on the base, 2–3 on the earlier whorls, about 8 on the body whorl. Length 4 mm.

Locality.—Bowen (J. Laseron), holotype.

Remarks.—This is a much longer and narrower species than *O. varicosa*, and has a slightly different protoconch and fewer axials and spirals, and the varices are narrow and sharp, not broad and flat.

OBTORTIO FABRICA, sp. nov.

Figs. 222–224

Shell relatively large, variable in form from conical to subcylindrical, colour also variable, the holotype (Fig. 222) and the specimen of Figure 224 pale straw with brown apex, that of Figure 223 golden brown with paler bands. Protoconch large, but smaller than in *O. ambiqua*, smooth, of 1½ whorls, the nucleus large, the next whorl inflated, sculpture beginning gradually as spiral keels. Mature whorls 7, of irregular growth, the holotype nearly conical, but in the specimen of Figure 224 narrower with the later whorls nearly equal. Whorls rounded and restricted at the sutures. Sculpture fine, the early whorls with spiral sculpture only; thence the axials and spirals are about equal in strength and beaded at their intersections, the axials fading below the periphery. The axials vary in number: on the holotype, 16, 20, and 24 respectively on the last 3 whorls; more on the median whorls of the specimen of Figure 223, and fewer on that of Figure 224. The spirals are numerous, about 8 on the median whorls and about 15 on the body whorl. Aperture small, ovate, outer and anterior margins thin and rounded, inner margin rounded and slightly reflected. Length of holotype 5·2 mm; Figure 223, 3·7 mm; Figure 224, 4·4 mm.

Locality.—Bowen (J. Laseron), not uncommon, holotype and 3 paratypes selected.

Remarks.—Even allowing for the variability in form and colour the much finer sculpture distinguishes this from other species with large protoconchs.

OBTORTIO CRASSA, sp. nov.

Fig. 225

Shell of medium size, elongate, subcylindrical, pure white. Protoconch large, smooth, of 1½ whorls, the nucleus large, the next whorl inflated, sculpture beginning gradually as faint spirals followed closely by the axials. Mature whorls 6, rounded, sutures deep, the spire for the last 4 whorls with only a slight but regular taper, body whorl relatively long. Sculpture strongly clathrate, the axials and spirals about equal, and rising to small tubercles at their intersections, the intervening pits regular and deep. The axials number 16 to the whorl and fade on the base. The spirals are strong, and on the base form prominent rounded ribs separated by narrow channels. They number 3–5 on the early whorls and 9 on the body whorl. Aperture ovate, rather elongate, extended anteriorly, outer and anterior margins thin and rounded, inner margin short, curved, and reflected over the columella. Length 3·5 mm.

Locality.—Michaelmas Cay (T. Iredale), holotype.

Remarks.—In form and protoconch this resembles *O. fabrica*, but it differs by the more elongate aperture and the much stronger sculpture, particularly by the fewer and much stronger spirals.

OBTORTIO DUPLEX, sp. nov.

Fig. 226

Shell small, broadly conical, spire slightly convex, colour uniformly brown. Protoconch large, smooth, of 2½ whorls, the nucleus small, the next 2 whorls nearly equal. Mature whorls 5, short, rounded, sutures deep. Sculpture clathrate, of strong, rounded axial ribs, 14 to the whorl, terminating below the periphery. Spirals narrower than the axials, but overriding them to produce a moderate tuberculation, broadening on the base where the last 4 are smooth. The spirals number 3–4 on the earlier whorls and 9 on the body whorl. Aperture small, ovate, outer and anterior margins rounded and thin, inner margin curved and reflected over the columella. Length 2·9 mm.

Locality.—Darwin (J. Laseron), holotype and 1 paratype.

Remarks.—Of the clathrate species this has the strongest axials, but the main character for specific separation is the protoconch, which has a whorl more than other species with large protoconchs.

OBTORTIO DIPLAX (Watson)

Figs. 227 and 228

Bittium diplax Watson, 1886, p. 555, pl. 38, fig. 34.

The type locality is Amboina, the length given being 0·099 in. or approximately 2·5 mm. The specimen figured is from Darwin, where it is not uncommon, and is 3·6 mm in length and rather more slender than the type. It is probably also more mature. The same species is also very abundant at Murray I., extending the range from the East Indies to the portals of the Pacific Ocean. The species is variable within limits, in both size and width, the specimen figured being about the mean between broader and narrower individuals, but the sculpture is constant, the most prominent feature being the 2 sharp spiral keels which give a pronounced angularity to the whorls.

IV. Acknowledgments

For the material forming the basis of this research the author is greatly indebted to Dr. J. W. Evans, Director of the Australian Museum, for permission to examine and study the Museum collections; to his son John Laseron, who collected thoroughly and widely at Darwin and at many localities on the Queensland coast; and to Miss G. Thornley, who collected a number of rissoids from Murray Island and Torres Strait. And more than anything the author is deeply grateful to Mr. Tom Iredale, who throughout has evinced the greatest enthusiasm and afforded advice and assistance. Many years ago Mr. Iredale had commenced a revision of the Australian rissoinas, and he now unselfishly made available all his original notes. This alone made comparatively easy the long and difficult task of research into the large and widely scattered literature. In addition Mr. Iredale sorted all the rissoids from the extensive collection he made at Michaelmas Cay, in itself no inconsiderable task. To him also is due the very rare material from Christmas Island.

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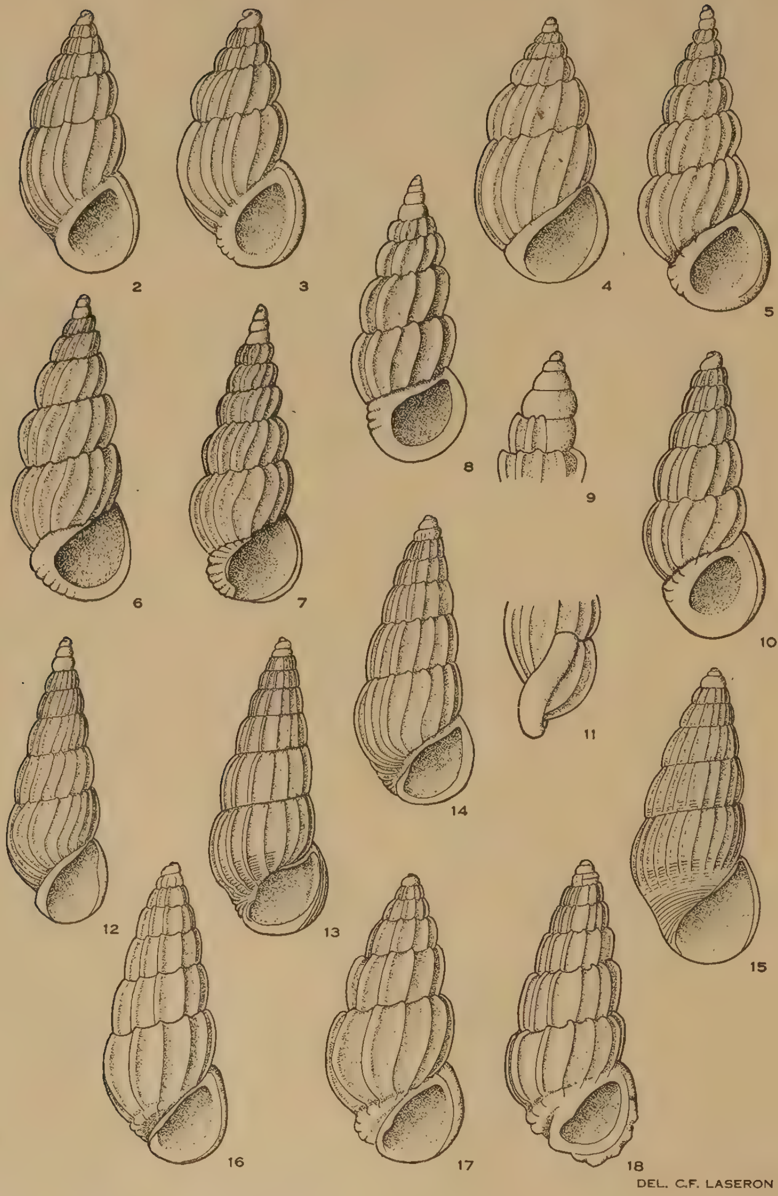

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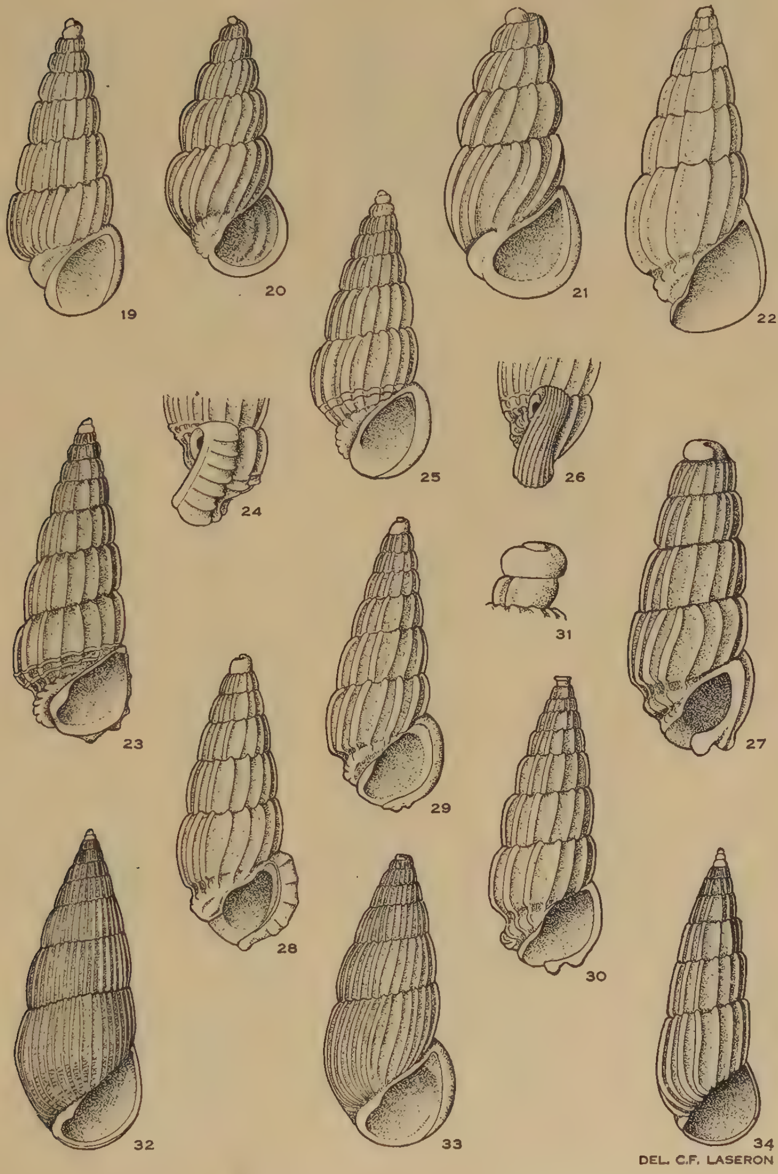

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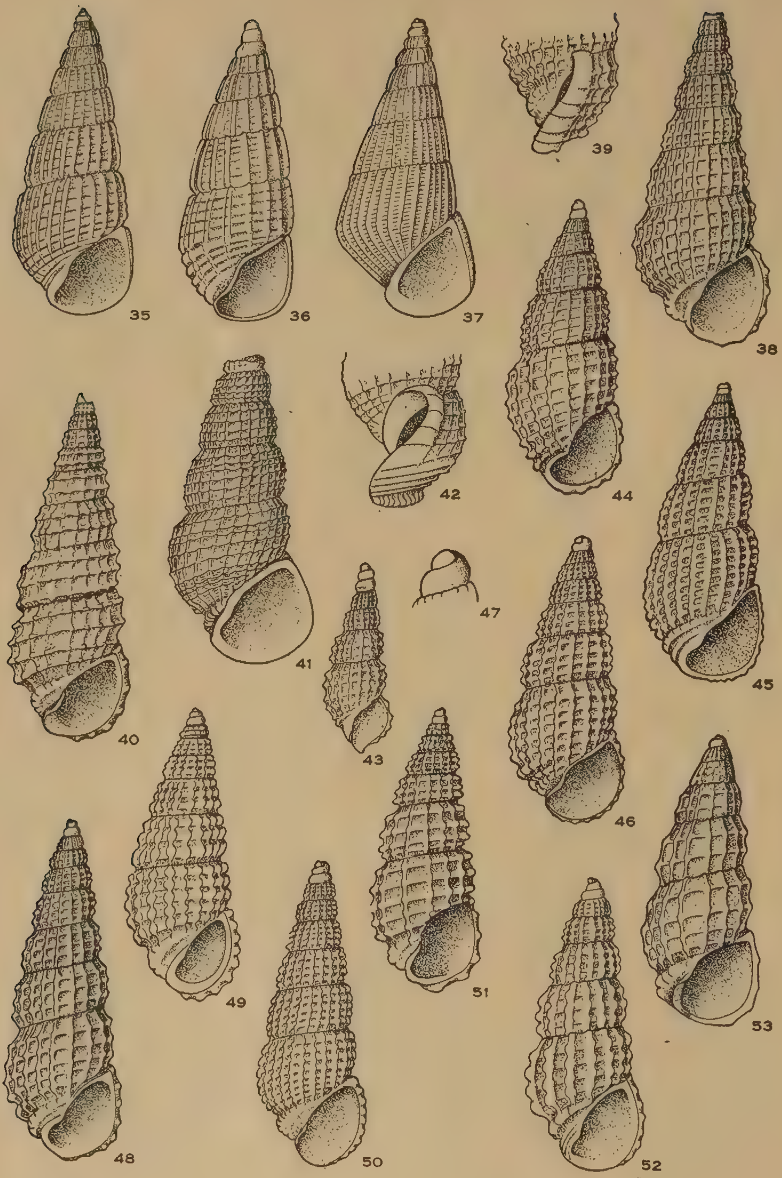

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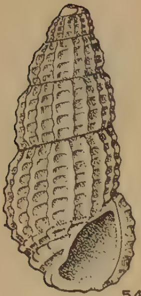
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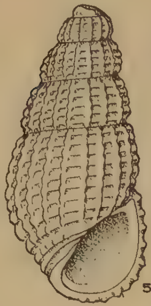
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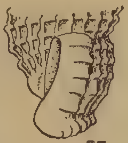
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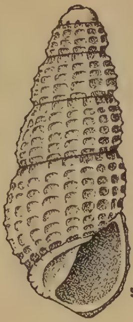
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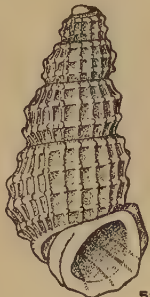
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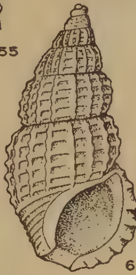
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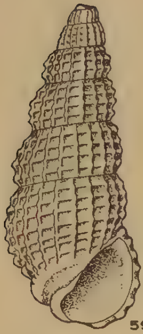
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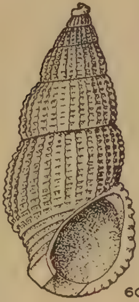
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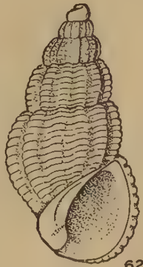
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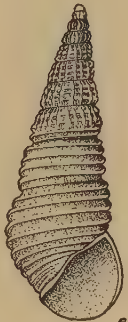
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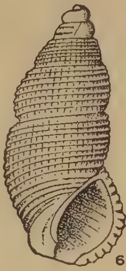
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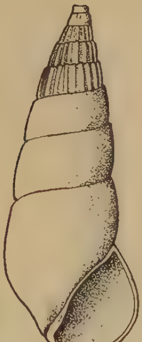
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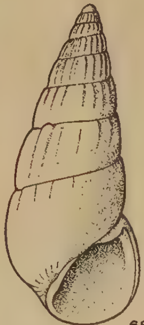
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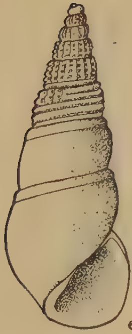
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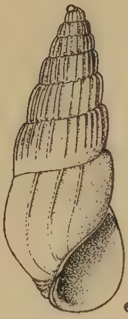
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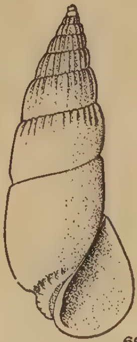
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Fig. 54.—*Planapexia fractura*, sp. nov. Holotype. × 11. Fig. 55.—*P. decepta*, sp. nov. Holotype. × 8. Fig. 56.—*Planapexia* sp. × 7. Fig. 57.—*Planapexia* sp. Aperture from side. Fig. 58.—*P. quadrina*, sp. nov. Holotype. × 7. Fig. 59.—*P. elevata*, sp. nov. Holotype. × 6½. Fig. 60.—*Isselia polytropa augerea*, subsp. nov. Holotype. × 9. Fig. 61.—*I. lateralis*, sp. nov. Holotype. × 8½. Fig. 62.—*I. undulata*, sp. nov. Holotype. × 11. Fig. 63.—*I. incisa*, sp. nov. Holotype. × 14. Fig. 64.—*Moerchiella efficata* (Brazier). × 5½. Fig. 65.—*M. efficata*. Variation. × 5½. Fig. 66.—*M. artensis* (Montrouzier). × 3½. Fig. 67.—*M. persista*, sp. nov. Holotype. × 7. Fig. 68.—*M. deleta*, sp. nov. Holotype. × 5. Fig. 69.—*M. volvera*, sp. nov. Holotype. × 4.

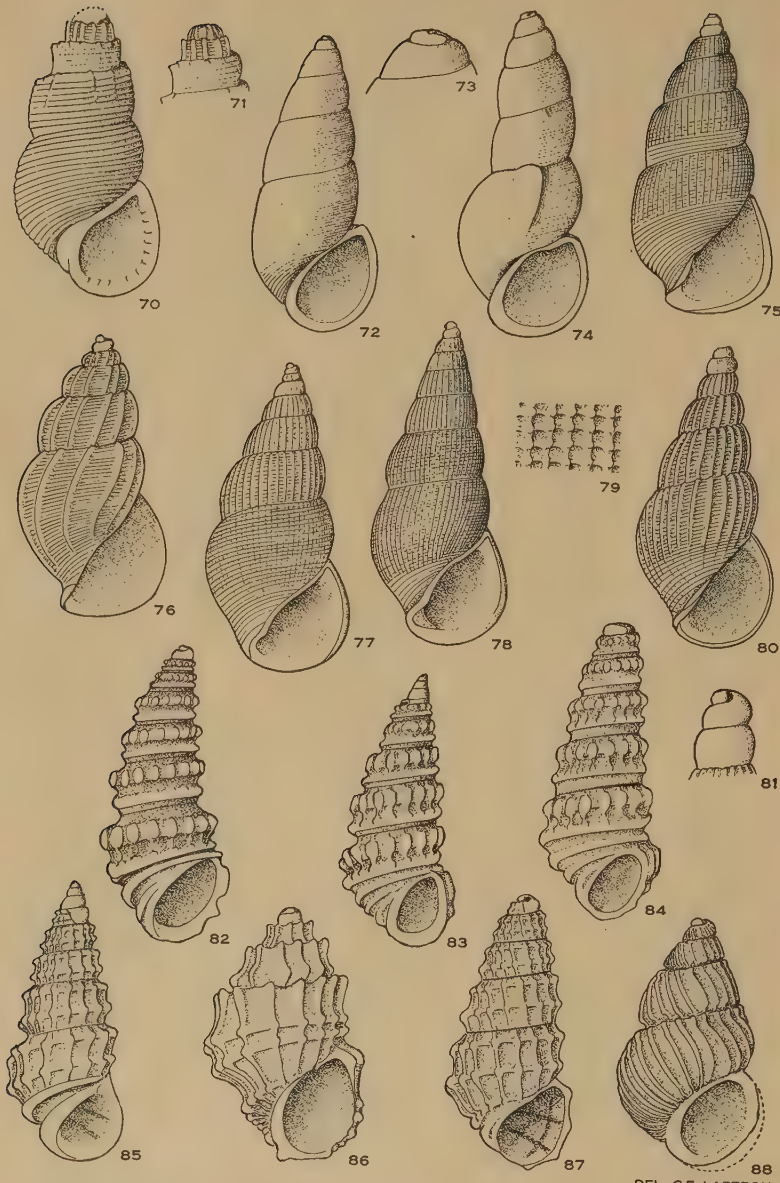

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Fig. 70.—*Dentrissoina thornleyana*, sp. nov. Holotype. × 4½. Fig. 71.—*D. thornleyana*. Apex of paratype. Fig. 72.—*Dipsotoma mercurialis* (Watson). × 7. Fig. 73.—*D. mercurialis*. Protoconch. Fig. 74.—*D. mercurialis*. Showing distortion. × 5. Fig. 75.—*Zymalata concinna*, sp. nov. Holotype. × 11. Fig. 76.—*Z. triangularis* (Watson). × 12. Fig. 77.—*Z. inermis* (Brazier). Typical. × 7½. Fig. 78.—*Z. inermis*. Variation. × 7. Fig. 79.—*Z. inermis*. Detail of sculpture. Fig. 80.—*Condylicia collaxis*, sp. nov. Holotype. × 11. Fig. 81.—*C. collaxis*, sp. nov. Protoconch. Fig. 82.—*Pyramidelloides pacifica*, sp. nov. Holotype. × 13. Fig. 83.—*P. turris*, sp. nov. Holotype. × 12. Fig. 84.—*P. cylindrica*, sp. nov. Holotype. × 10. Fig. 85.—*P. viticula*, sp. nov. Holotype. × 14. Fig. 86.—*Herewardia kesteveni* (Hedley). (After Hedley.) × 10. Fig. 87.—*Costabieta paucina*, sp. nov. Holotype. × 13. Fig. 88.—*Contraxiala obliqua*, sp. nov. Holotype. × 13.

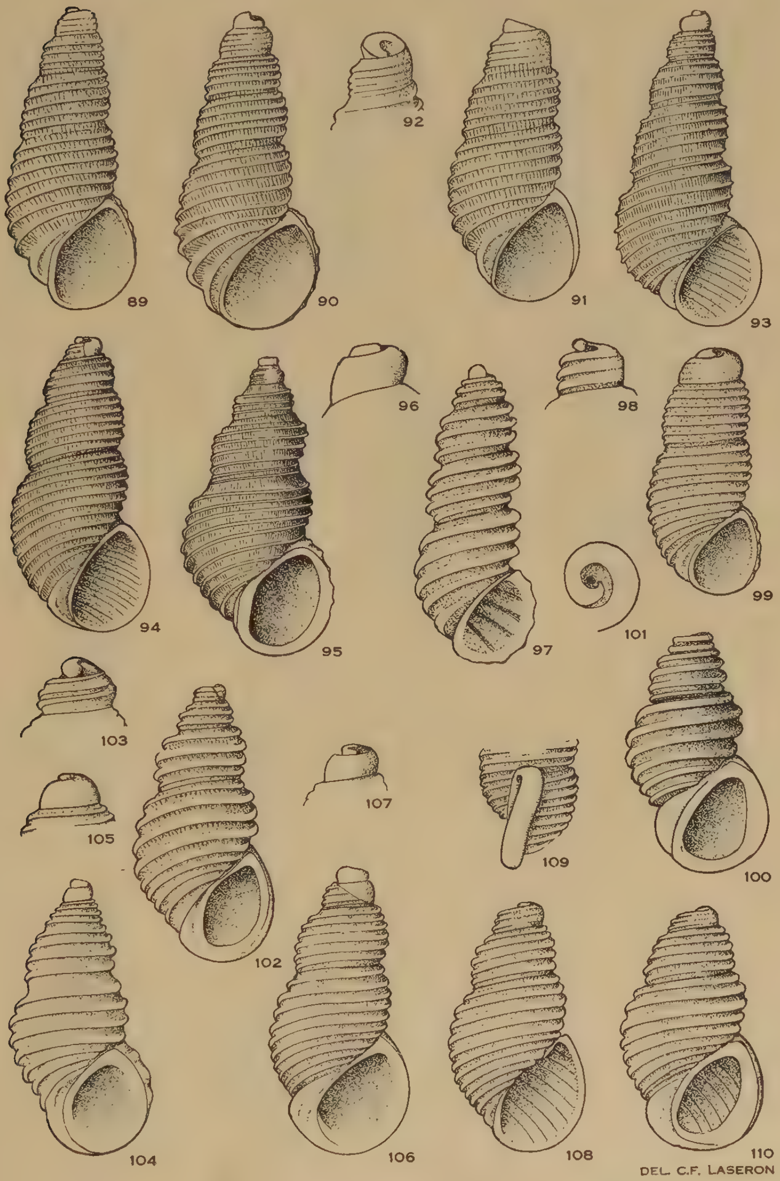

Fig. 89.—*Pellamora australis* (Hedley). (After Hedley.) × 7½. Fig. 90.—*P. australis*. From Darwin. × 5½. Fig. 91.—*Pellamora* sp. × 5. Fig. 92.—*Pellamora* sp. Protoconch viewed obliquely. Fig. 93.—*P. laseroni* Iredale. × 12. Fig. 94.—*P. reflecta*, sp. nov. Holotype. × 13. Fig. 95.—*P. angulata*, sp. nov. Holotype. × 7. Fig. 96.—*P. angulata*. Protoconch. Fig. 97.—*P. diminuta*, sp. nov. Holotype. × 17. Fig. 98.—*P. diminuta*. Protoconch. Fig. 99.—*P. minatura*, sp. nov. Holotype. × 17. Fig. 100.—*P. truncata*, sp. nov. Holotype. × 10. Fig. 101.—*P. truncata*. Protoconch from above. Fig. 102.—*P. carpentariensis* (Hedley). × 10. Fig. 103.—*P. carpentariensis*. Protoconch. Fig. 104.—*P. carpentariensis*. Another specimen. × 8½. Fig. 105.—*P. carpentariensis*. Protoconch. Fig. 106.—*P. capitata*, sp. nov. Holotype. × 15. Fig. 107.—*P. capitata*. Protoconch. Fig. 108.—*P. spiralis*, sp. nov. Holotype. × 13. Fig. 109.—*P. spiralis*. Aperture from side. Fig. 110.—*P. amplexa*, sp. nov. Holotype. × 10.

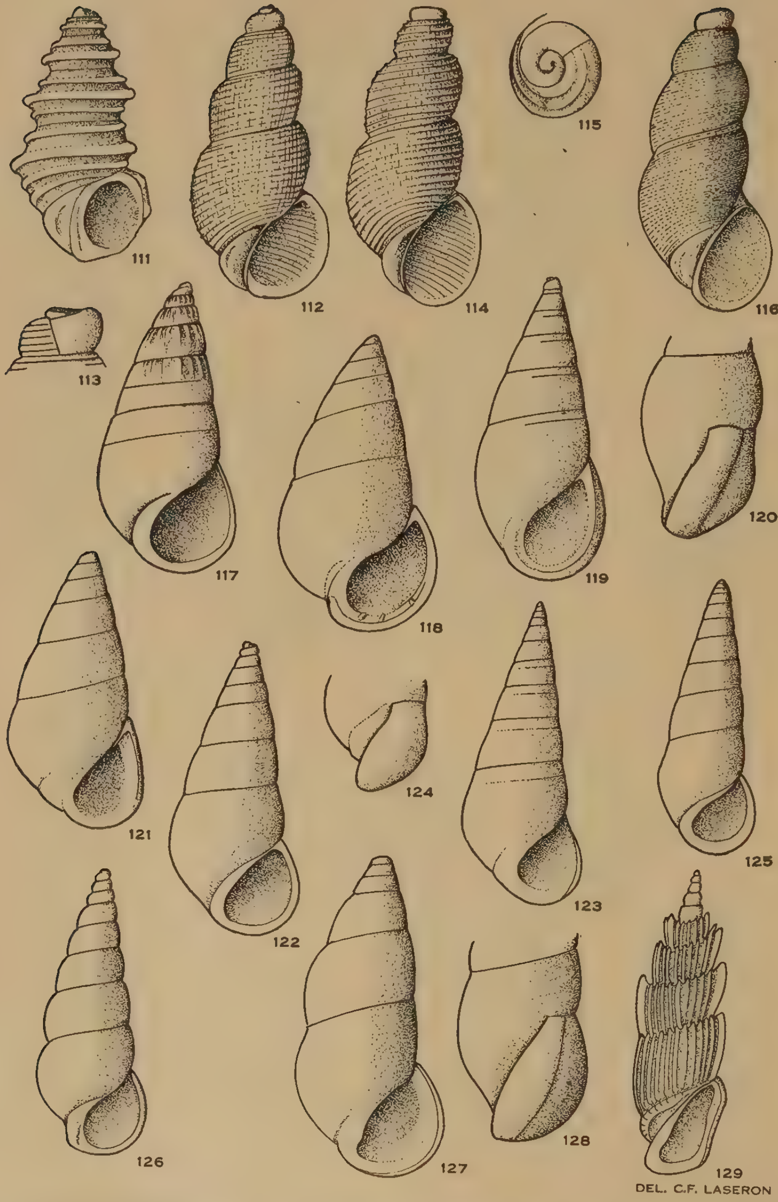

Fig. 111.—*Chrystella islandica*, sp. nov. Holotype. × 22. Fig. 112.—*Lucidinella conicera*, sp. nov. Holotype. × 13. Fig. 113.—*L. conicera*. Protoconch. Fig. 114.—*L. conicera patruelis*, subsp. nov. Holotype. × 18. Fig. 115.—*L. conicera patruelis*. Protoconch from above. Fig. 116.—*L. sublevis*, sp. nov. Holotype. × 16. Fig. 117.—*Zebina heronensis*, sp. nov. Holotype. × 10. Fig. 118.—*Z. tridentata* (Michaud). × 4. Fig. 119.—*Z. nitens*, sp. nov. Holotype. × 11. Fig. 120.—*Z. nitens*. Aperture from side. Fig. 121.—*Z. hebes*, sp. nov. Holotype. × 12. Fig. 122.—*Z. isolata*, sp. nov. Holotype. × 11. Fig. 123.—*Z. acicula*, sp. nov. Holotype. × 9½. Fig. 124.—*Z. acicula*. Aperture from side. Fig. 125.—*Z. linearis*, sp. nov. Holotype. × 11. Fig. 126.—*Z. constricta*, sp. nov. Holotype. × 11. Fig. 127.—*Z. inflata*, sp. nov. Holotype. × 5. Fig. 128.—*Z. inflata*. Aperture from the side. Fig. 129.—*Palisadia subulata*, sp. nov. Holotype. × 12.

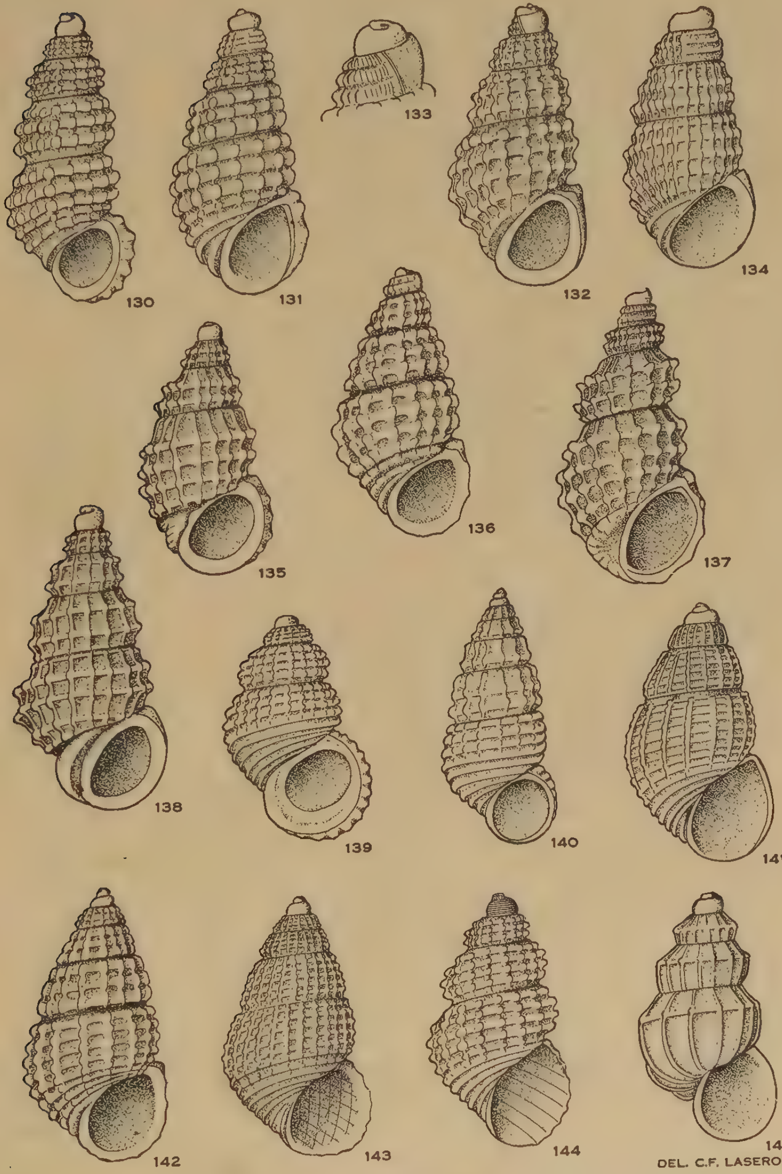
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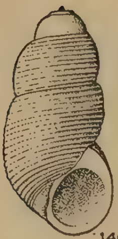
Fig. 130.—*Merelina queenslandica*, sp. nov. Holotype. × 18. Fig. 131.—*M. solida*, sp. nov. Holotype. × 12½. Fig. 132.—*M. sucina*, sp. nov. Holotype. × 12. Fig. 133.—*M. sucina*. Protoconch. Fig. 134.—*M. reversa*, sp. nov. Holotype. × 12. Fig. 135.—*M. humera*, sp. nov. Holotype. × 12. Fig. 136.—*M. corruga*, sp. nov. Holotype. × 18½. Fig. 137.—*M. goliath*, sp. nov. Holotype. × 8½. Fig. 138.—*M. goliath*. Variation. × 10. Fig. 139.—*M. hians*, sp. nov. Holotype. × 29. Fig. 140.—*Discrevinia balba*, sp. nov. Holotype. × 19. Fig. 141.—*Haurakia novarensis trajectus* (Watson). × 13½. Fig. 142.—*H. firma*, sp. nov. Holotype. × 12. Fig. 143.—*H. formosita*, sp. nov. Holotype. × 11. Fig. 144.—*H. isolata*, sp. nov. Holotype. × 22. Fig. 145.—*Parashiela ambulata*, sp. nov. Holotype. × 20.



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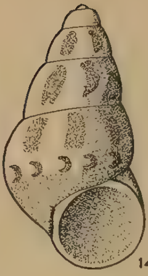

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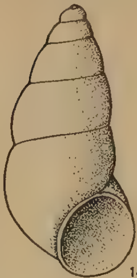

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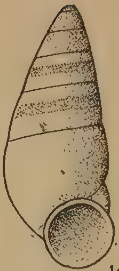

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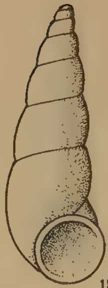

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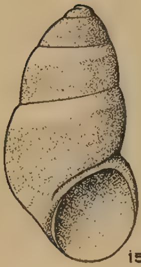

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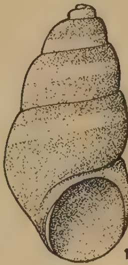

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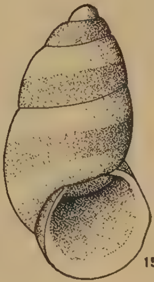

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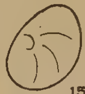

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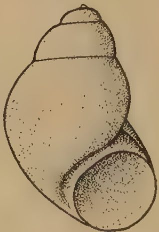

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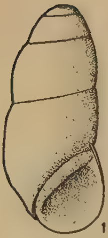

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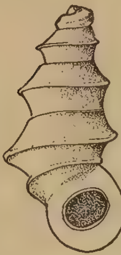

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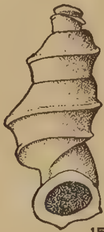

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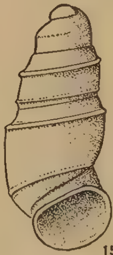

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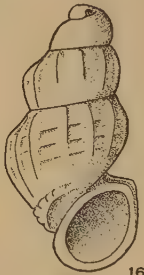

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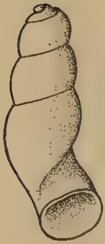

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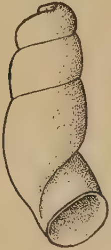

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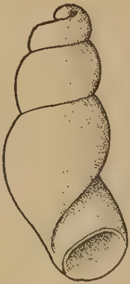

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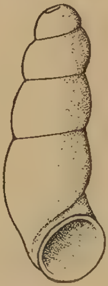

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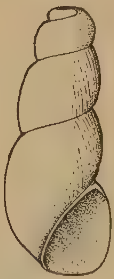

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Fig. 146.—*Botelloides glomerosa* (Hedley). (After Hedley.) × 10. Fig. 147.—*Estea lunata*, sp. nov. Holotype. × 19. Fig. 148.—*E. perdigna*, sp. nov. Holotype. × 15. Fig. 149.—*E. eurychades* (Watson). (After Watson.) × 12. Fig. 150.—*E. xanthias* (Watson). (After Watson.) × 30. Fig. 151.—*Scrobs tropica*, sp. nov. Holotype. × 28. Fig. 152.—*S. compressa*, sp. nov. Holotype. × 21. Fig. 153.—*S. incipiens*, sp. nov. Holotype. × 22. Fig. 154.—*S. fulcira*, sp. nov. Holotype. × 37. Fig. 155.—*S. fulcira*. Operculum. Fig. 156.—*S. oblata*, sp. nov. Holotype. × 20. Fig. 157.—*Anabathron ascensum* Hedley. (After Hedley.) × 16½. Fig. 158.—*A. contortum* Hedley. (After Hedley.) × 24. Fig. 159.—*A. lene* Hedley. × 32. Fig. 160.—*Emblanda emblematica* (Hedley). × 19. Fig. 161.—*Saltatricula protractus* (Hedley). × 26. Fig. 162.—*S. ballerina*, sp. nov. Holotype. × 27. Fig. 163.—*S. stringera*, sp. nov. Holotype. × 24. Fig. 164.—*S. improrsa*, sp. nov. Holotype. × 26. Fig. 165.—*Nanadoma imitoris*, sp. nov. Holotype. × 22.

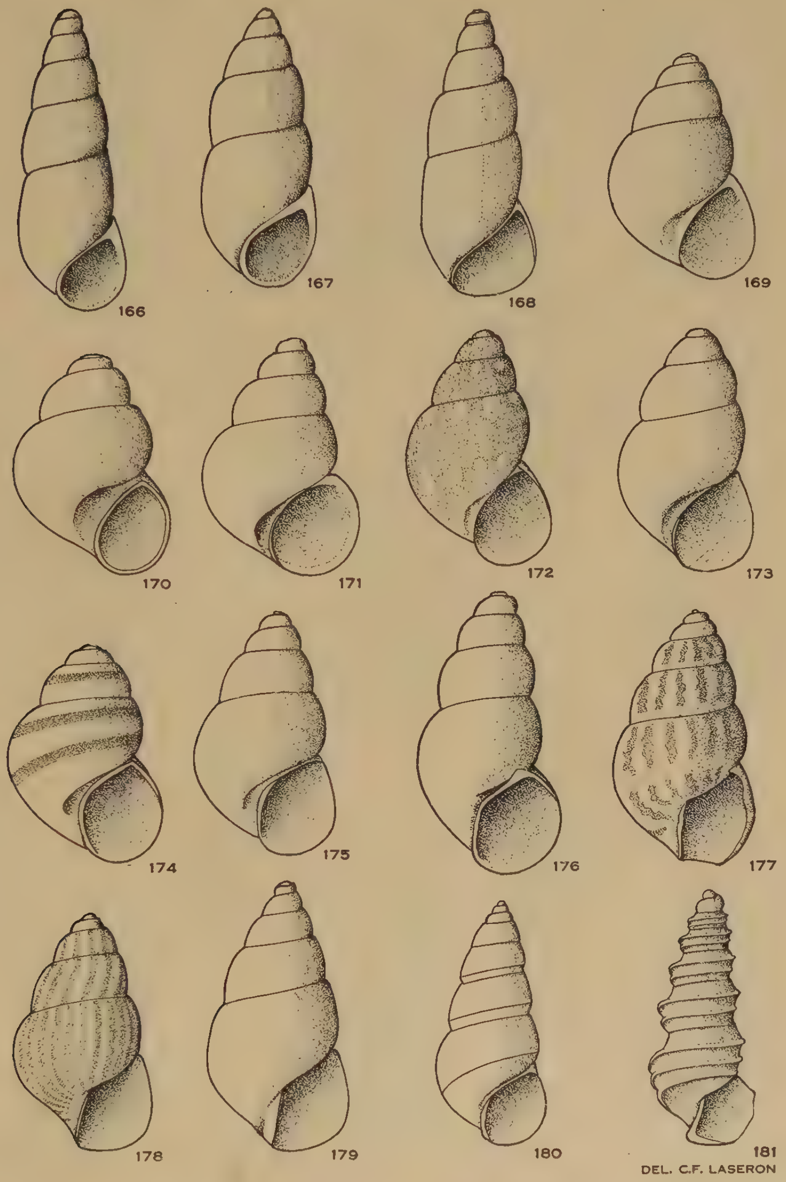

Fig. 166.—*Epigrus dissimilis* (Watson). × 14. Fig. 167.—*E. obesa*, sp. nov. Holotype. × 14½. Fig. 168.—*E. truncata*, sp. nov. Holotype. × 11½. Fig. 169.—*Lucidestea vitrea*, sp. nov. Holotype. × 18. Fig. 170.—*L. perforata*, sp. nov. Holotype. × 19. Fig. 171.—*L. obesa*, sp. nov. Holotype. × 24. Fig. 172.—*L. maculosa*, sp. nov. Holotype. × 26. Fig. 173.—*L. laterea*, sp. nov. Holotype. × 20. Fig. 174.—*L. capricornea* (Hedley). (After Hedley.) × 19. Fig. 175.—*L. sublacuna*. sp. nov. Holotype. × 16. Fig. 176.—*Mesodestea resima*, sp. nov. Holotype. × 12. Fig. 177.—*Vitricithna marmorata* (Hedley). (After Hedley.) × 17. Fig. 178.—*V. marmorata*. Variation. × 16. Fig. 179.—*V. relativa*, sp. nov. Holotype. × 21. Fig. 180.—*Mellitestea simplex*, sp. nov. Holotype. × 21. Fig. 181.—*Cyclonidea carina*, sp. nov. Holotype. × 12.

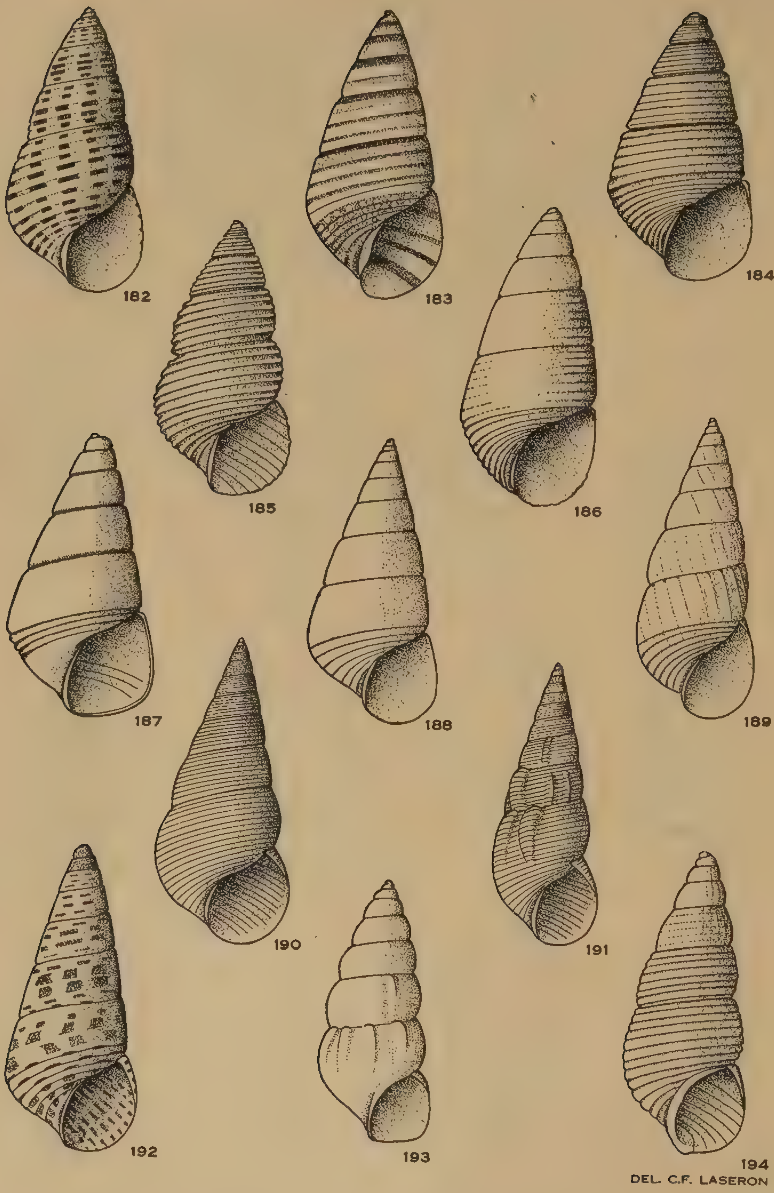
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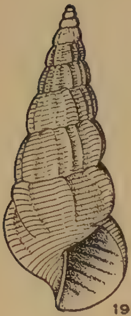
Fig. 182.—*Diala albugo* (Watson). × 15. Fig. 183.—*D. conspicua*, sp. nov. Holotype. × 14. Fig. 184.—*D. fossa*, sp. nov. Holotype. × 11½. Fig. 185.—*D. premeris*, sp. nov. Holotype. × 11½. Fig. 186.—*D. watsoni*, nom. nov. × 15. Fig. 187.—*D. planalba*, sp. nov. Holotype. × 17. Fig. 188.—*D. cacumenata*, sp. nov. Holotype. × 9. Fig. 189.—*D. vestigia*, sp. nov. Holotype. × 8. Fig. 190.—*D. diffilata*, sp. nov. Holotype. × 6. Fig. 191.—*D. diffilata*. Variation. × 7. Fig. 192.—*D. cento*, sp. nov. Holotype. × 6. Fig. 193.—*D. tumerosa*, sp. nov. Holotype. × 17. Fig. 194.—*Paradiala supraflecta*, sp. nov. Holotype. × 9.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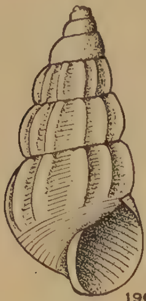
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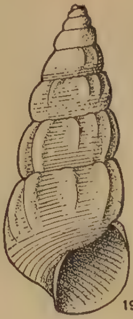
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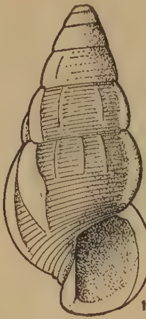
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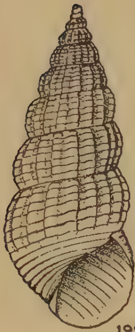
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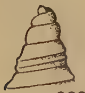
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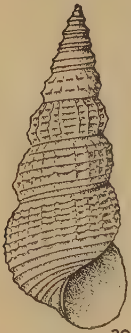
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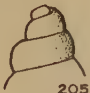
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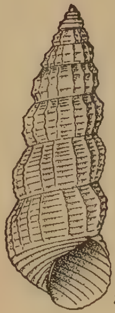
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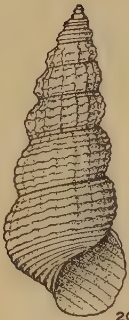
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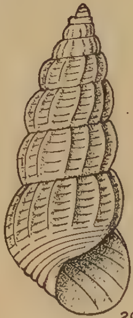
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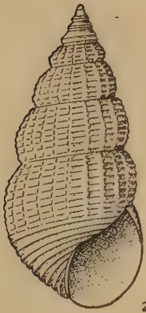
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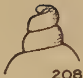
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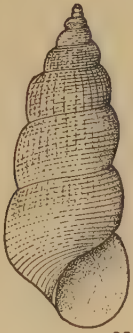
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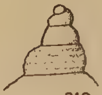
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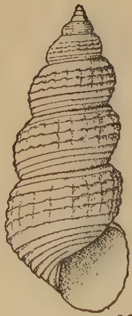
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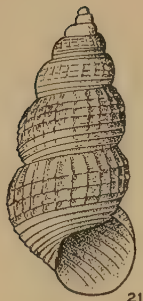
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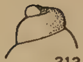
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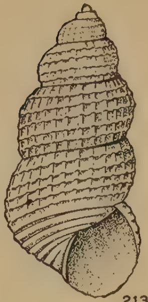
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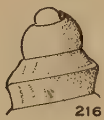
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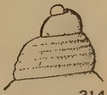
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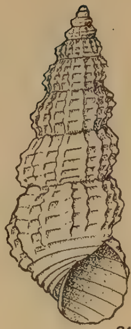
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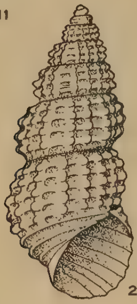
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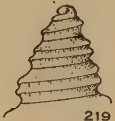
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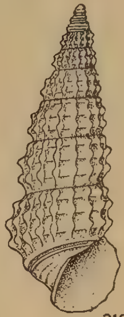
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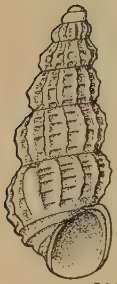
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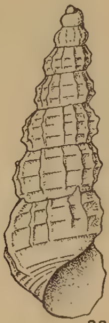
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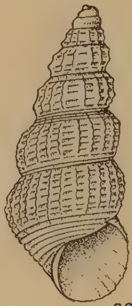
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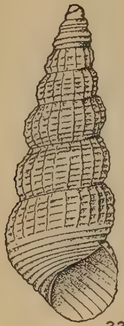
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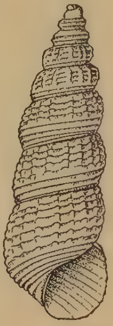
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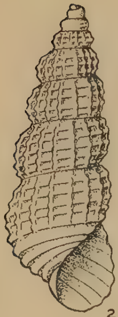
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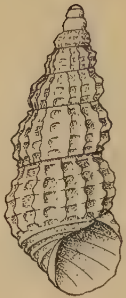
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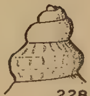
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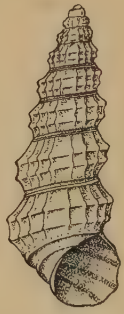
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Fig. 211.—*Obtortio columna*, sp. nov. Holotype. × 12½. Fig. 212.—*O. columna*. Protoconch. Fig. 213.—*O. columna*. Variation. × 15. Fig. 214.—*O. columna*. Protoconch. Fig. 215.—*O. vulnerata* Hedley. × 11. Fig. 216.—*O. vulnerata*. Protoconch. Fig. 217.—*O. perparvula progreda*, subsp. nov. Holotype. × 14. Fig. 218.—*O. rugosa*, sp. nov. Holotype. × 11. Fig. 219.—*O. rugosa*. Protoconch. Fig. 220.—*O. varicosa*, sp. nov. Holotype. × 11½. Fig. 221.—*O. ambiqua*, sp. nov. Holotype. × 10. Fig. 222.—*O. fabrica*, sp. nov. Holotype. × 7½. Fig. 223.—*O. fabrica*. Variation. × 11. Fig. 224.—*O. fabrica*. Variation. × 9. Fig. 225.—*O. crassa*, sp. nov. Holotype. × 11½. Fig. 226.—*O. duplex*, sp. nov. Holotype. × 13. Fig. 227.—*O. diplax* (Watson). × 11. Fig. 228.—*O. diplax*. Protoconch.

CORRIGENDA

VOLUME 7, NUMBER 1

Page 106, Pelecypoda, between *Brachyodontes hirsutus* and *Chama imbricata: Insert family name* Chamidae. Between *Chama reflexa* and *Perna nucleus: Insert family name* Isognomontidae.

Page 107, Balanidae: *For Tetraclita cerulescens read Tetraclita coerulescens.*

Page 124, Figure 12: *For Brachiodontes read Brachyodontes.*

Page 127, line 6: *For Ornithochiton read Onithochiton.*

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